

Rhododendron ponticum:

**A guide to management on nature
conservation sites**



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PURPOSE OF THIS GUIDE

This guide is intended for use by ecologists, foresters, managers of nature conservation sites, and those carrying out control 'on the ground'. It seeks to provide a detailed summary of the available information about rhododendron which is relevant to its impacts on nature conservation and especially to its management. The information provided is based on review of published literature and consultation with a wide group of people who have experience of rhododendron and its management.

A list of reading material is provided at the back of this document.

Appendix 1 provides a summary and evaluation of field methods that have been employed by the National Parks and Wildlife Service (NPWS), both currently and in the past.

All methods described here should be carried out with due care and consideration to health and safety requirements, and where necessary, by trained and competent operatives.

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INTRODUCTION

Preamble

Rhododendron ponticum is a large broadleaved, evergreen, shrub that was introduced into the British Isles from Iberia during the 18th century. Planted into demesne lands and woodlands for ornament and game cover, it has since become widely naturalised on suitable sites throughout Ireland. In areas with sufficiently acid soils, and particularly where the mild climate allows, rhododendron has invaded woodland, plantation forestry and to a lesser extent, heath and bog. In many places it has replaced the native shrub layer and grows in dense thickets excluding native vegetation below and limiting natural tree regeneration.

In order to meet the nature conservation objectives at such sites, some management of rhododendron is required so that the status of native habitats may be improved. However, control of rhododendron is not straightforward; throughout Britain and Ireland various agencies have spent time and resources in attempting to control this plant and have found that it is an ongoing battle. Some of the most seriously affected areas are remote and over difficult terrain. Rhododendron regrows vigorously when cut, and is very resilient to herbicide treatments so that effective herbicidal control requires very specific conditions. In addition, mature plants produce abundant seed, annually in suitable sites, and reinfestation of cleared areas is a significant hindrance to management. Many different approaches to the problem have been used, with varying success at different sites.

Rhododendron

Rhododendron ponticum is one of more than 900 types of rhododendron. Most of these are native to Asia and especially north-west China, and many are present in the British Isles as part of horticultural collections. The rhododendrons are members of the heather family and so are related to, and share many characteristics with, native plants such as ling (*Calluna vulgaris*), bell heather (*Erica cinerea*) and the strawberry tree (*Arbutus unedo*). Fossil deposits show that during interglacial times, (the Gortian Interglacial tentatively proposed as having occurred from 425,000 to 300,000 years ago) *Rhododendron ponticum* was present in forests across Europe and Ireland along with species such as scot's pine (*Pinus sylvestris*), silver fir (*Abies alba*), holly (*Ilex aquifolium*) & Norway spruce (*Picea abies*). Since the most recent ice-age however, the natural distribution of *Rhododendron ponticum* has been restricted to the area south of the Black Sea and to a handful of sites in Spain and Portugal (see figure 1 overleaf).

Box 1 - Rhododendron Fast Facts: Background

- Although there are more than 900 species worldwide, only one type of rhododendron (*Rhododendron ponticum*) is invasive in Irish habitats.
- It is native to the Black Sea area of Eastern Europe and is present at a few sites in Spain and Portugal where it is an endangered species.
- Rhododendron was introduced to gardens and woodlands in Britain and Ireland from the 1760s onwards. It was planted for ornament, shelter and as cover for game (deer and fowl) in woodlands.
- *Rhododendron ponticum* is relatively hardy and easy to grow in the Irish climate. In some cases it was used as a rootstock for other Rhododendron types.

Rhododendron was first introduced to Britain in 1763, at a time when explorers were collecting plant and animal specimens from all over the world. Recent genetic studies have concluded that the plants from which today's populations derive were of Iberian rather than Turkish origin. Some plants sampled from wild populations in eastern Scotland and northern England have been found to have hybridised with a north American species (*Rhododendron catawbiense*) which is a popular plant in rhododendron collections. This plant is more frost tolerant than the common rhododendron and may pass this characteristic on during hybridisation. There was no evidence of this having occurred in Irish populations, although only a small number of Irish plants were sampled.

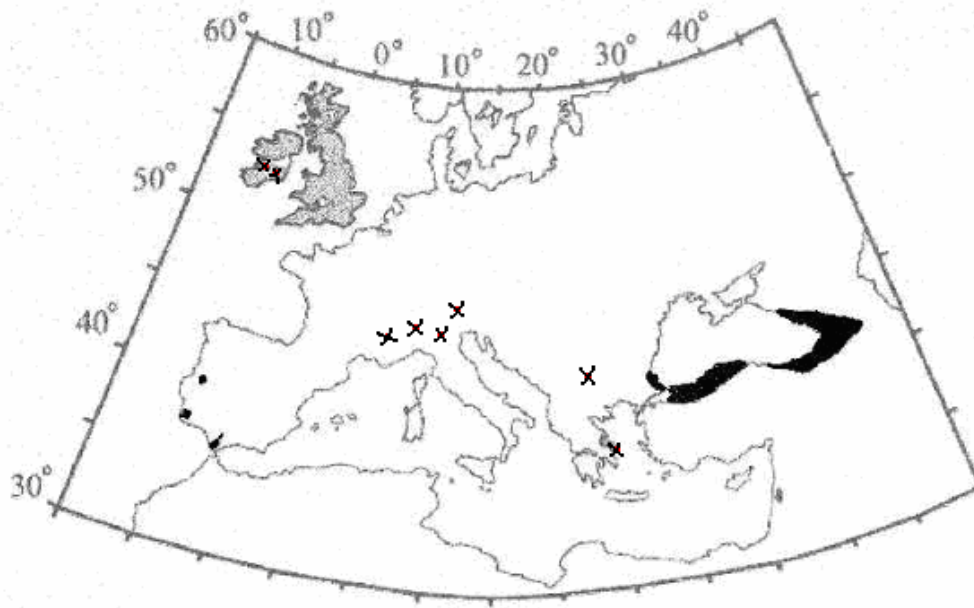


Figure 1: Distribution of *Rhododendron ponticum* in Europe. Solid black area indicates current native distribution, 'X's indicate locations of interglacial fossil finds, mottled grey area indicates area where the plant is naturalised today. (Adapted from Milne & Abbot 2000 and Jessen et al. 1959).



Rhododendron has been planted for shelter near exposed homesteads and for ornament and game cover in woodlands.

Box 2 - Rhododendron Fast Facts: Growth Habit

- Rhododendron thrives on well drained, acid soils in mild, damp climates, and has naturalised in such situations across Britain and Ireland. It is less vigorous on wetter substrates and on more neutral and base rich soils.
- Rhododendron is evergreen. It has thick, waxy leaves that are very effective at absorbing and reflecting light. Mature plants cast a deep shade.
- Rhododendron can grow in full sunlight and in the shade of other trees. Very heavy shade, such as that cast by dense conifer stands, will retard growth, but rhododendron can grow vigorously below deciduous trees such as oak, birch and mountain ash.
- Young plants of rhododendron grow slowly, initially from a single stem. For the first 4 years, leaves are arranged singly, in a spiral along the stem. After this, loose whorls of leaves are produced. After about 10 years (or earlier if the shoot is damaged) the plant may become multi-stemmed.
- Mature plants can clump and extend laterally to meet neighbouring plants, forming dense thickets. This can occur within about 25-30 years of establishment.
- In the open, rhododendron plants form relatively low, compact dome shapes, with many stems, and typically 2-4m tall. In woodland, stems reaching up toward the light generally result in the plants being taller, up to 8m or more, and branches become interwoven using each other and other trees for support.
- In wetter situations, branches, still attached to a parent plant, and touching the ground may produce roots and give rise to another plant (layering). This is relatively rare in drier situations.
- The roots of rhododendron usually form a compact, relatively shallow root ball. In large plants on dry sites, this is typically of the order of 30cm³ – 60cm³. In wetter sites, the roots may be shallower but wider.
- Because of the multi-stemmed habit and the capacity to layer, aging rhododendron is difficult. Plants can live for at least 100 years and perhaps for longer. In northeast Turkey, there are reports of plants up to 400 years old.
- Rhododendron has relatively few insects associated with it in Ireland and Britain, and is poisonous to grazers such as sheep, deer and cattle.

Box 3 - Rhododendron Fast Facts: Reproduction I

- Rhododendron reproduces mainly by the production of large amounts of seed.
- Plants begin to flower at c. 10-12 years old in optimal conditions (e.g. south west Ireland). Where conditions are less ideal (e.g. more exposed, shorter growing season e.g. Eastern Scotland) flowering may not begin until later, perhaps up to 20 years.
- In optimal conditions, flowers are produced every year, and flowering and seed set is more abundant in the open and in broken canopy than under closed canopy. In less ideal conditions, flowering may be restricted to plants growing in more open conditions and may not occur every year.
- Flowers range in colour from lilac to deep magenta and have orange – brown spots on the petals. They are each c.6cm in diameter and are borne in flower-heads (inflorescences) consisting of c.10-20 individual flowers.
- Flowering is concentrated around a two week period some time between May and June. The timing of flowering is affected by altitude, aspect and location (latitude). Outside of the main flowering period, small numbers of flowers have been observed at Killarney in all months of the year.
- Rhododendron flowers produce large amounts of pollen and nectar and attract a wide range of insect visitors, including bumble-bees which are thought to be the main pollinators. Rhododendron is apparently unable to self-pollinate spontaneously.



Rhododendron may begin flowering at c.10-12 years and in good conditions can flower every year thereafter

Box 4 - Rhododendron Fast Facts: Reproduction II

- Successfully fertilised rhododendron flowers mature into capsules over a period of approximately 6 months. The capsules dry out and seed may be found from December onwards, but the majority of seed in south west Ireland is released between January and March.
- Rhododendron seeds are very tiny, c.1.5mm long and 0.5mm wide. They are light (average 0.063mg), oval in shape, and bear a frill of tiny hairs at each end.
- Very large amounts of seed are produced by rhododendron. A single bush in Killarney that was in the semi-open and 2 metres tall by c.10 metres circumference produced more than 1 million seeds (Cross 1973).
- Rhododendron seed is dispersed by wind, water and on vectors (animal fur, human clothing etc.)
- Depending on conditions, it is thought that rhododendron seed may be dispersed by wind for distances up to about 1km. This will be affected by wind speed, local geography and local vegetation. The majority of seed is likely to be dropped much closer to the parent plant, probably within 100m. This is especially so in a woodland situation.
- Wind direction will have an important impact on the dispersal of seed. This will be influenced by the prevailing winds during the seed dispersal period and also by local topography.



a



c



b

Rhododendron flowers are pollinated by bees and other insects in May & June and the fruit capsules (a) mature slowly on the plant. By January the tiny seeds (c) are ripe and the capsule dries out (b) and releases them.

Photographs by Jane Stout

Box 5 - Rhododendron Fast Facts: Seedling Establishment

- Rhododendron seeds, once exposed to moisture (i.e. in the soil/on vegetation) must germinate within 1 year, although at some sites, a small number appear to survive for longer. Seed stored in a dark, dry environment can certainly survive for more than one year.
- Light is required for germination, but only at low levels (2% daylight resulted in 17% germination after 49 days).
- Rhododendron seeds are so tiny that they do not contain any food reserves for the young seedling (as in say oak or hazel). Therefore, seedlings can only establish in certain conditions.
- Successful germination and establishment is very rare on leaf litter (e.g. of rhododendron or Oak/holly woodland), and among dense herbaceous vegetation (e.g. among grasses and woodrush). The tiny root must be able to access a reliable water supply almost immediately on emergence. Thin mossy carpets, rotten logs, and in sufficiently humid/wet conditions, bare peat or soil are suitable seed bed for establishment.
- Summer drought and winter frost are main causes of seedling mortality, and so seedling establishment will be confined more strictly to ideal conditions (rotten logs, damp mossy patches) where the climate is more extreme.
- In heath and bog environments, seedlings may establish on vertical peat banks that are nearly always moist, along stream-sides and ditches, and where grassy tussocks provide sufficient moisture.
- In sufficiently humid situations (e.g. many of the Killarney oakwoods) seedlings can establish successfully in forks in mature trees and on mossy branches.



Where dense leaf litter or regular flooding prevents rhododendron germination, a rotting stump or fallen log provides a suitable seed bed

Box 6 - Rhododendron Fast Facts: Which sites are more susceptible to invasion?

- It appears that climate has a significant impact on rhododendron and its capacity for invasion of semi-natural habitats. This is probably via 2 mechanisms:
 1. Impact on flowering age, abundance, & amount of seed set. Milder, moister climates, such as that of south west Ireland, facilitates annual flowering and abundant seed production from 10-12 years. Flowering and hence seed set is likely to be delayed in more harsh/continental climates and flowering may not occur in mature plants every year.
 2. Impact on seedling establishment & survival– seedlings in more humid and milder climates may achieve establishment in otherwise less than ideal conditions e.g. on mineral soil. Where less mild climate prevails, such sites may be unsuitable for seedling establishment and seedling mortality may be very high.
- Areas with many suitable germination sites that contain a seed source or are downwind from one will be invaded more quickly. On open landscapes such as heath and bog, invasion may follow the pattern of watercourses and ditches, which provide most suitable establishment sites.
- Heavily grazed woodland with an abundance of mossy patches and logs, or bare peat or soil in humid conditions, will be quickly invaded.
- Areas which were previously heavily infested with rhododendron and which after clearance have developed a widespread thin mossy carpet (usually 2-3 years after clearance) are easily re-infested by seed.
- Woodlands with a well developed field layer with a high cover of grasses and herbs will be more slowly invaded.
- In wet woodlands, the relatively drier sites of mossy tree limbs and hummocks will provide germination sites while areas that are prone to waterlogging will be less affected. However, plants that established in drier parts of wet woodlands may spread vegetatively into the wetter parts by layering.
- Woodlands with a deep carpet of persistent leaf litter (e.g. beech & oak woodlands over flatter ground) will offer fewer germination sites.
- Grassland where the sward is dense (either grazed or ungrazed) offers relatively few germination sites and so is usually slow to be invaded.
- Generally, heath and bogs are invaded slowly, as germination sites are restricted to ditch and drain edges, wet vertical cuttings, and, less frequently, grassy tussocks.
- Although rhododendron is best adapted to more acid soils, it has naturalised on soils with a pH range of 3.3 – 6.4.

Ramoran's Blight (*Phytophthora ramorum*) and Rhododendron

Phytophthora ramorum is the scientific name of a fungal pathogen that can cause damage to various garden species (rhododendrons, viburnums) and tree species. Having escaped into the natural woodlands in parts of the United States, it has resulted in the death of many American native oak and tan oak trees, and became commonly referred to there as 'Sudden Oak Death' disease.

Under the EU Plant Health Directive emergency legislation was introduced in 2002 to prevent the introduction into and the spread of *Phytophthora ramorum* within the EU. Since 2003, annual surveys have been carried out throughout the EU, and *Phytophthora ramorum* has been found in a number of EU member States including Ireland. The vast majority of findings have been on rhododendron and viburnum species. However, the fungus has been found in Great Britain on a range of tree species including a number of oak species, beech, ash, sycamore, Spanish chestnut and horse chestnut. In the Netherlands it has been found on beech and red oak.

In Ireland, *Phytophthora ramorum* has been found on rhododendron at three forest locations, including Killarney National Park, and containment/eradication measures have been implemented. The pathogen has also been detected in garden centres and nurseries on rhododendron and viburnum. To date there have been no findings on any tree species in Ireland. On rhododendron, it causes a twig and leaf blight with browning/blackening of leaf stalk, bases and tips, stem damage and wilting, but it generally does not kill these 'carrier hosts'. However, when the infection in these carrier hosts achieves a certain level, the blight may then pass on to susceptible adjacent trees in which it can potentially cause lethal bleeding cankers of the trunk.

If suspicious symptoms are observed on rhododendron or on any tree species please contact the Forest Service, Department of Agriculture, Forestry & Food (contact details are supplied below). If following laboratory analysis *Phytophthora ramorum* is detected, the Department will advise on control measures in accordance with EU technical guidelines.

Further advice is available from Forest Protection & FRM Section, Forest Service, Department of Agriculture, Forestry & Food, Kildare Street, Dublin 2. Tel: 01 6072651 or forestprotection@agriculture.gov.ie

HOW TO MANAGE RHODODENDRON AT NATURE CONSERVATION SITES

Rhododendron control may be considered at two levels:

1. Management planning for rhododendron control;
2. Physical removal and killing of the plant.

In all sites, appropriate methods of removal and killing individual rhododendron plants will have to be properly applied in order to achieve successful control. The application of a carefully planned and strategic approach to this will be very important at large sites with extensive infestation, and less so at small sites and those which have only a small rhododendron problem.

Whatever the scale of the problem, successful and efficient rhododendron management will be most easily achieved when certain basic information is considered. This includes facts about rhododendron in general, and facts about rhododendron at the site in question. Detailed general information about rhododendron has already been given. In addition to this, important features of rhododendron, relevant to its management, are outlined in Box 7.

Box 7 – Factors relevant to management

- Rhododendron regrows vigorously when cut back. Cutting away branches and stems alone will not give long-term control of rhododendron.
- Regrowth from cut stumps is more multi-stemmed than the original growth.
- Regrowth from rhododendron that has been cut back may produce flowers from as early as 3-4 years after cutting back.
- Rhododendron plants that have grown from seed may begin to produce flowers from as early as 10-12 years, and in optimum conditions will flower annually thereafter.
- The thick waxy leaves of rhododendron do not absorb herbicides easily. Older leaves are harder to treat. Ideally both older and younger leaves should be present when applying herbicides.
- Herbicides applied to rhododendron only affect the stem which is treated. Any untreated stems will be unaffected by the herbicide.
- Large stands of rhododendron that have been cut back and left so that the regrowth is allowed to flower may produce more seed than the original stand did prior to management.

Management planning for rhododendron control

While the reason for rhododendron control at any nature conservation site may be generally described as 'conservation' or 'habitat restoration', the specific details of these will vary at each site. Site managers will need to consider their particular sites, the habitats and species present and their conservation status and requirements, and rhododendron control may well be only one part of a wider management requirement.

Without ever leaving the office, the site manager will have a general idea of the extent of the rhododendron problem on-site. By considering some or all of the factors in Box 8, a more detailed understanding may be gained. Depending on the scale of the problem and the resources available, one of two general approaches may be adopted.

1. Where resources will allow for the clearance of the major seed producing stands of rhododendron within 2 or 3 working seasons then these should be targeted first. Concurrently, or otherwise as early as resources allow, other areas of rhododendron should be tackled, dealing with the oldest stands first, the idea being to minimise the amount of seed production. Remember, rhododendron grown from seed typically begins to flower and set seed from about 10-12 years onwards. Cut stumps will show regrowth (unless chemically treated) and such regrowth can flower within 3-4 years.
2. If there is a large amount of rhododendron present, scattered in various locations across a larger site, and resources do not allow for clearance across the entire site within a relatively short time-frame, then a deeper understanding of the situation will be required. In such a case, the rhododendron should be mapped and described and blocks of work prioritised for clearance. When prioritising blocks for clearance, consider the following:
 - Areas which are already severely infested will not deteriorate further in 10-15 years, but areas that are currently lightly to moderately infested will degenerate into more dense severe infestation with resulting habitat deterioration within 10-15 years.
 - Clearing from the outside-in will minimise the reinfestation by seed from outside of the management block.

Bearing these in mind, the following approach to prioritisation of work blocks is proposed:

Level I: Highest Priority

- Maintenance of well cleared areas and areas that are still rhododendron free
- Consolidation of any previous work, where a reasonable level of clearance over the larger part of the area has been achieved.

Level II: High Priority

- Areas of native habitat type with slight – moderate infestation levels
- Relatively small areas of more severe infestation within a larger area that falls into Level I or II
- Areas of very high conservation value e.g. containing rare or protected species, regardless of infestation level.

Level III: Moderate Priority

- Areas of non-native habitat with slight – moderate infestation levels, especially those located such that they will act as a seed source into Level I or II areas.
- Areas of native habitat with severe infestation, especially those located such that they act as a seed source into clear, cleared or higher priority areas.

Level IV: Low Priority

- Large continuous tracts with severe and very severe infestation levels, especially where access and terrain mean that most of the area will be difficult to clear. Where such areas are identified they should be contained, until such time that all higher priorities have been met and then such areas should be dealt with according to the prioritisation criteria used above.

Box 8 - Things to consider when planning management

- Consider the entire site.
- Consider:
 - How much rhododendron there is;
 - Where the rhododendron is;
 - What kind of rhododendron there is – Describe the plants – height, clumped or not, thicketing or not, layered or not, previously cut;
 - The kind of access to the infested areas there is;
 - The kind of terrain that is present.
- Specify the objectives. It may be total eradication or partial eradication or containment. It may include habitat restoration, tree regeneration or conservation of a particular species.
- Consider:
 - Which areas do you want to impact most - areas not yet badly affected or the worst affected areas.
 - How the rhododendron is behaving - Is it expanding? Is the seed source confined to one area? Is the entire site susceptible to invasion by seed? Are there rhododendron stands outside of your control that impact the site?
- Consider whether once the management programme has begun, new areas will continue to have seedling establishment. Consider to what degree cleared areas will be affected by reinfestation from seed.
- Consider the habitat types present and whether they are subject to fast invasion.
- Consider the grazing regime. Can manipulation of this assist in preventing reinfestation? Will fencing be required to allow recovery of the native vegetation and to prevent or minimise reinfestation?
- Are there any plans for disturbance to ground layer e.g. timber extraction, that may become a hotspot for invasion from rhododendron?
- Consider the condition of the vegetation in the areas already infested. Will rhododendron removal render them very susceptible to fast invasion? Can this be mitigated against?
- Consider which techniques are appropriate to the site, the rhododendron present and the objectives?
- Are there sensitive species/habitats or other issues (e.g. public access/interest) that I must consider?
- Consider the resources available and how to maximise return on them.

Getting the most from your management

Once blocks have been prioritised for clearance, it is then necessary to choose appropriate eradication techniques (see below). Whatever the technique chosen there are some basic standards that, if applied, will maximise the effectiveness and efficiency of control.

Rhododendron regrows vigorously when cut. Cutting alone renders subsequent regrowth more difficult and expensive to manage and may increase flowering and thus seed production. *Except in sites where new infestation from seed is not a problem, or where the limited area of infestation allows easy management, cutting of stands of rhododendron should not be undertaken unless a follow up programme is well planned and resourced.*

In order to most efficiently control rhododendron in nature conservation sites, one basic principle is advised, irrespective of site variables:

Once rhododendron management has begun, do not allow any rhododendron plant to flower and set seed within areas that have undergone initial clearance.

In order to achieve this, there are two facts to consider:

A plant grown from seed will generally not produce flowers until it is approximately 10-12 years old. This age data refers to south west Ireland. The age at which flowering begins may be later in more exposed sites and sites with more harsh climates. Gather local knowledge. If in doubt, err on the side of caution.

A plant which is growing from a cut stump is capable of flowering within 2 years, although usually flowering in this situation begins at 3-4 years. Again, plants growing in less optimal environments than that in south west Ireland, may take longer before flowering begins.

All eradication techniques can result in total kill. However, most of the time, the kill achieved is less than 100%, and quality control and repeat treatments are an important part of every control programme.

To prevent seed production within a site once clearance is initiated, two concepts must be adopted:

1. Zero tolerance of rhododendron within the work area (and preferably a cleared buffer zone)
2. Do not allow new seed infestation to mature and itself become an on-site seed source

Clearance should be complete within each management block. Every rhododendron plant should be eradicated. This is especially important on sites that are vulnerable to infestation from seed.

Where seed input to the site will persist after initial clearance has been undertaken (i.e. from plants outside of the management block) a programme to deal with seedlings will be required.

The difficulty involved in killing rhododendron and thus successfully eliminating it from an area in a single work phase means that management of an infested area will almost always require several work phases over a number of years. In sites where the entire seed source cannot be eliminated in one work phase, reinfestation by seed will require ongoing management.

Box 9 - Basic standards for application during control works within management blocks

- Adopt zero tolerance to rhododendron
 - It is very important that every rhododendron plant is removed during initial clearance. The overlooking of even a handful of plants can result in the development of a significant source of reinfestation. As a general rule of thumb, plants achieve c.10cm height in 4/5 years in woodland conditions. If all plants of this size and greater are sought and removed during primary clearance, then younger plants can be overlooked safely so long as they are tackled later during suitably timed subsequent work phases.
- Cover site systematically
 - In woodland, only systematic coverage of the worksite can allow confidence that all large and visible plants have been removed. This is especially important where most of the plants being removed are seedlings (i.e. in Phase 3 maintenance). Systematic coverage and consequent complete removal of seedlings will allow that sites be swept for seedlings at as long an interval as possible without any risk of plants achieving flowering and seed production.
- Maintain a tidy work site
 - Whatever the phase of work, control method or the level of infestation being cleared, careful treatment of brash and pulled/snipped seedlings will increase the efficiency of the work. Pulled plants lying on the ground will obscure vision and increase the likelihood of missing plants. Discarded pulled seedlings with roots will also be in danger of re-rooting in some circumstances. Untidily discarded brash will inhibit full access to the site for later work phases and may also cause plants to be missed during that work phase.
- Observe the fine details of the control method in use
 - Rhododendron is very resilient to many control methods so the fine detail of each must be carefully observed.
- Apply high standard of quality control
 - Even when carried out to a high standard, control methods may not be 100% effective and quality control will be required at all work phases. This should ensure that all plants were treated or removed and that treatment was effective.
- Training and competency of operatives in prescribed control methods
 - It is necessary that operatives are fully aware of the fine details of the control method which they are applying, and that all work is carried out to the highest standard.
- Good policing/supervision of clearance work
 - This is required to ensure that operatives (who may not have the same level of motivation as management) carry out work to the standards outlined above.
- Accurate record keeping including mapping
 - This is particularly relevant in large and complicated sites where there are many separate work blocks, each with its own management history. Because rhododendron management of a block requires several work phases over many years, accurate record keeping is required. This will help to ensure that maintenance schedules will be adhered to even if personnel change.

Physical removal & killing of the plant: Terminology

Preliminary Clearance (Phase 1) [Year 1]

This is initial clearance of rhododendron from an infested site that is carried out during a single initial work phase. It includes the cutting of large plants and removal of all visible smaller plants. It may also include stump treatment and direct foliar treatments. The uprooting or extraction of stumps is also an option but may not be appropriate on many nature conservation sites.

Advanced Clearance and Final Clearance (Phase 2) [Year 1-3]

This is achieved during the second visit to a site that has already undergone phase 1 (i.e. preliminary) clearance. Its purpose is to ensure the effectiveness of phase 1 clearance and to check for, and deal with, any plants that may have been missed. It is best carried out early in the year before native vegetation has grown or in May/June as flowering plants will then be easily spotted.

Where stump treatment or uprooting was carried out during phase 1, advanced clearance involves quality control, i.e. ensuring that all previously treated rootstocks have been successfully killed, and the re-treating of any remaining regrowth. If regrowth is found, a second phase 2 visit will be required to ensure that this re-treatment has been effective.

Where stumps were untreated during phase 1, foliar treatments are carried out at this stage. Where this is the case, a further phase 2 visit will be necessary to ensure the success of the foliar treatment (i.e. quality control).

This visit is also necessary to remove any plants that were missed during phase 1 clearance, in particular those that were present as small seedlings at the time.

Final clearance has been achieved when all mature plants that were present at the time of preliminary clearance are dead, and when systematic coverage of the site has ensured that all plants aged approximately 5 years and older have been removed.

Initial Maintenance (Phase 3) [Year 8]

All cleared sites in an area where seed input is ongoing, (from external seed sources) will require ongoing management so that reinfestation from seed is not allowed to succeed. This is to meet the basic clearance objective of maintaining cleared areas free of seed producing rhododendron. This part of the management scheme is as important as phases 1 and 2 if the control programme is to succeed in the medium to long term. Some resources will be required to facilitate this part of the scheme, but they should be substantially less than that required for phases 1 and 2. Maintenance visits should be timed so that the site is kept free of seed producing rhododendron as efficiently and effectively as possible. Rhododendron plants germinated from seed will not themselves produce seed until they are at least 10 years old. Thus if the manager is confident that no rhododendron seed has been produced on site since preliminary clearance (phase 1) was completed, and also that systematic coverage of the site has ensured that at the completion of phase 2 (Final Clearance) no plants are younger than 5 years old, then the first maintenance visit may be delayed until up to 5 years after the completion of Phase 2.

Phase 3 clearance involves the removal of plants which established in the 2/3 years prior to preliminary clearance or since preliminary was carried out (from in-blown seed). Thus any plants

found should be no older than 10 years, and most should be 5-8 years old. If the site is systematically covered and all visible plants (c. 5 yr old plant will be c. 10cm tall) are removed, then it can be reasonably confidently assumed that no plant will flower within the site for at least another 8-10 years.

Ongoing Maintenance (Repeat Phase 3) [Every 6-8 years after Year 8]

As long as an external seed source remains, repeated systematic sweeps through the site will be required, to prevent newly established plants from reaching flowering age and setting seed.

Systematic Sweep

The heterogeneous nature of the terrain and the inherently poor visibility mean that systematic coverage is required when carrying out phase 2 and 3 clearance in woodland sites. On open ground, plants will almost always be visible above surrounding vegetation before achieving flowering age and so less methodical coverage may be acceptable, although this will require a more frequent monitoring schedule as plants may be older than 5 years before one can confidently assume that they will be seen and removed. In woodland however, systematic coverage of the entire area by lines of operatives is the only practical way to ensure that all visible plants will be spotted for removal. Such work is ideally carried out in late winter/early spring when the vegetation is at its lowest and visibility of rhododendron seedlings is best.

Clear

In large sites where seed sources persist nearby and where large areas are susceptible to infestation or reinfestation, a zero-tolerance approach to rhododendron within clearance sites must be adopted in order to gain maximum benefit from control measures and also to make management most effective and cost efficient in the medium to long term.

Thus, previously infested sites should be considered as clear of rhododendron only if they have been systematically checked and no mature (seed producing) plants are present and the site is part of an ongoing maintenance schedule (at phase 3 stage).

Quirke (1991) proposed that 'A location will be deemed clear of rhododendron at a particular time if it meets each of the following criteria:

1. The location has been systematically checked for rhododendron within the last ten years and any rhododendron found has been eliminated;
2. No seed producing rhododendron has been present within a radius of 50m in the previous 4 years;
3. The location has been systematically cleared of rhododendron seedlings at least 3 years after the last seed was produced.

This will mean that:

1. Any area that has not been systematically checked within the last 10 years cannot be classified as clear of rhododendron.
2. Any area that has been systematically checked, and in which no rhododendron with seed capsules has been found, and in which all other rhododendron if any (i.e. small plants which

have not yet flowered) have been removed, can be classified as clear of rhododendron for the following 8 years.

3. Where a seed producing rhododendron is found and removed, the area within 50 m radius (of the seed producing plants) cannot be classified as clear for a period of at least four years, and only if it has been revisited and systematically cleared of seedlings at least three years after the last seed was produced.

Adoption of such a rigorous definition will mean that areas maintained in such 'cleared' condition will not revert to dense rhododendron nor will they become a seed source for new infestation.

CONTROLLING RHODODENDRON – TECHNIQUES FOR ERADICATION OF PLANTS

There are various approaches to eradication of rhododendron plants (see Appendix 1 for further details on these methods and their results). All of these methods are valid in certain sites and under certain conditions. Each has its particular merits and limits. There is no single 'right way' to control rhododendron. The appropriate approach can only be decided after examination of the site involved, the age and type of infestation, consideration of any previous management, the resources available and other factors such as fragility of the habitat.

A variety of approaches are available and in most sites a combination of methods will be most appropriate. Some methods may have high disturbance associated with them, which render them less appropriate for use on nature conservation sites.

In every case, *attention to the fine detail* of any given method is essential in order to achieve effective rhododendron control. Failure of a particular method is almost always because of poor technique or lack of necessary 'follow-up' work.

Be aware that effective rhododendron control in the field can be very difficult and demanding work, requiring fastidious attention to detail and complete thoroughness in approach. Weather, remote work location and challenging terrain often render working conditions very difficult. Therefore it is important to be realistic in your expectations when choosing a method and costing work.

The range of control options available for different rhododendron infestation types are summarised below. These are listed in Table 1, and further detail on each is provided later.

I: Young plants - single stemmed, typically < 10 years old & up to 1m tall

- Plants may be cut off as close to the ground as possible (with secateurs or pruning saw) and the stem treated with herbicide.
- Plants may be pulled by hand, if necessary loosening the adjacent soil with a mattock or pick axe.
- Foliage may be sprayed with herbicide.

II: Isolated plants, typically >10 years old

- The plant may be cut down to the stump, as low to the ground as possible and the stump treated with herbicide.
- If access to the base of the main stems is possible, stem application of herbicide may be used.
- If low growing enough (usually less than 1.5m) foliage may be sprayed with herbicide.
- The plant may be cut to the ground/low stump and regrowth later treated with herbicide.
- The plants may be cut to c. 40cm above ground, each stem broken off from the root and the root treated with herbicide (New method under trial, see p. 28).
- If chemical treatments are not an option, the only alternative method of killing to rootstock is stump extraction. This may be done manually (using a mattock) or mechanically.

III: Mature stands of dense rhododendron

- The plant may be cut down to the stump, as low to the ground as possible and the stump may be treated with herbicide.
- If access to the base of the main stems is possible, stem application of herbicide may be used.
- The plant may be cut to the ground/low stump and regrowth later (after c. 18 months) treated with herbicide.
- The plant may be cut to the ground/low stump and regrowth later knocked off and the stump collar treated with herbicide.
- If chemical treatments are not an option, the only alternative method of killing the rootstock is stump extraction. This may be done manually (using a mattock) or mechanically, but the use of heavy machinery on nature conservation sites is often inadvisable.

Table 1 Rhododendron eradication techniques for large plants

Method	Factors critical to success	Other issues
Cut plants to ground level & treat stumps with herbicide	Immediate herbicide application Requires low cut * Chemical and concentration used Ensure all stumps treated (dye) Dry conditions required Quality control is required	Main kill achieved in single work phase Less herbicide used Very low risk of herbicide drift Reduced soil disturbance
Apply herbicide directly to stem	Chemical and concentration Timing of herbicide application Weather requirement Quality control is required	Requires access to stem base Very low risk of herbicide drift Very low volumes of herbicide used Standing dead rhododendron
Cut plants to ground level & spray regrowth/ spray standing plants <i>Herbicide Options: Glyphosate (water or emulsion based) Triclopyr</i>	Completeness of spraying Dry weather & 6 hours after Timing of herbicide application (month) Chemical and concentration used Adjuvant used Age of regrowth Quality control is required	Need for second major work phase Time delay in completing initial kill Damages native vegetation and may delay recovery by several years May facilitate reinfestation of rhododendron Less effective on waterlogged plants Standing dead rhododendron
Cut plants to ground level, knock off regrowth after 12-18 months & treat stump collar with herbicide	Requires low cut * Chemical and concentration used Ensure all stumps treated (dye) Dry conditions required Quality control is required	Need for second major work phase Less herbicide used & very low risk of herbicide drift Reduced soil disturbance
Extraction of rootball/ or entire plant <i>Machine mounted bucket/fork</i>	Entire rootball must be extracted Quality control required	Requires site to be accessible Potential damage to mature trees & their roots High soil disturbance. Risk of erosion & run off
Cut plants and grub out stumps	Entire rootball must be extracted Quality control is required; some herbicide use may be necessary	Very labour intensive Moderate soil disturbance

* There are also several new rhododendron control methods under trial at Killarney National Park and these are described in more detail in Appendix 1.

Herbicidal control & rhododendron

In almost all cases, some element of herbicidal control will be required for successful rhododendron management. **Herbicide treatments should always be carried out by a competent operator.** There are several different ways of applying herbicides to rhododendron, each suited to different situations.

The thick waxy cuticle of rhododendron foliage and the multi-stemmed growth habit greatly complicates herbicide application to this species. It is imperative that close attention to detail is followed when undertaking herbicidal control of rhododendron. If the recommended practices are carefully applied then complete kill is achievable.

Herbicides that are available for use in rhododendron control include Triclopyr (e.g. Garlon 4™) and Glyphosate. Glyphosate is widely accepted as a very effective herbicide for rhododendron control and various formulations are available e.g. Roundup™, Hilite™. The recommendations given here are based on the results of trials and programmes that have used Roundup.

Glyphosate works by interrupting the production of vital proteins (e.g. phenylalanine, tyrosine and tryptophane) that are produced in plants by a process called the Shikimic Acid Pathway. It is a broad spectrum herbicide that will damage all types of green plant. The enzyme which glyphosate inhibits is not present in animals and glyphosate has no known toxic effects on animals. On contact with soil, glyphosate quickly and strongly attaches to soil particles and so is 'locked' in the soil and other plants cannot absorb it and suffer damage. Following treatment with glyphosate, symptoms develop gradually and plant death may not be observed for several months:

- Treated plants stop growing very rapidly;
- Symptom development after that often occurs very slowly;
- Chlorosis (yellowing) on leaves occurs gradually, often in a mottled or interveinal pattern;
- These symptoms are usually most evident on newer growth;
- Necrosis and tissue destruction follow;
- Underground perennial plant parts (rhizome buds, rootstock buds) become necrotic and brown;

Due to the growth habit and internal transport system in rhododendron, herbicides are not moved around the plant between adjacent stems. Therefore, when applying herbicide, each individual stem of each plant must be treated in order to kill the plant. In foliar treatments, each leaf should be thoroughly wetted by the herbicide, to the point of 'run-off'. The aim is to get the herbicide into the root system, killing off the rootstock and causing plant death. For foliar applications, best results are achieved when both old (>1 year) and new growth is present at time of application.

As the leaves of rhododendron are so thick and waxy, absorption of the herbicide may be quite slow. In order to assist this, an adjuvant (substance that helps the herbicide stick to the leaf surface) can be used. Roundup™ Biactive contains an adjuvant and so additional adjuvant is not necessary when using this particular formulation.

Rain water (and other water) will wash herbicide off of the leaves so it is absolutely vital that herbicide is applied in dry conditions and that the treated plants remain dry for at least 6 hours after application. A longer dry period may be required in very high or very low temperatures (which slows the rate of herbicide uptake by the plant).

Box 10 - Rhododendron & herbicides

- Rhododendron is best controlled using *systemic* herbicides.
- Systemic herbicides are those that on entering the plant tissue are transported downwards to the roots and other areas of growth within the plant. (*Contact* herbicides are those that kill the tissue to which they are applied. They are not absorbed into and moved around within the plant.)
- Systemic herbicides must be absorbed by the plant and must enter the plant's transport system. The transport system of a plant is made up of special cells (xylem & phloem) which in woody plants, are located just beneath the bark of the stem in the cambial tissue, and in the veins of each leaf.
- The plant's transport tissue normally carries water and minerals from the soil upwards through the roots to the leaves, and food manufactured by photosynthesis in the plant leaves, downwards to the root system.
- In rhododendron, transport between each stem and the root system is independent i.e. if a substance travels between a given stem and the root system, it will not be transported into other stems, even on the same plant.
- **When applying herbicide to rhododendron every individual stem must be treated.**
- Rhododendron has a thick waxy cuticle (skin) on the surface of its leaves. The purpose of this is to help the plant to retain water, but it also acts as a barrier, inhibiting the movement of substances such as herbicides into the plant tissues.
- Therefore, movement of herbicide into rhododendron via its leaves can be very slow. If the herbicide is washed away (by rain) or evaporates (in warm weather or wind) before enough has been absorbed, treatment will not be effective.
- The use of another chemical (an adjuvant) can help the herbicide 'stick' to the surface of the rhododendron and increase the amount of herbicide actually absorbed into the plant. Some herbicides are sold in formulations that include added adjuvants.
- Other herbicides are provided in an emulsion type carrier that helps faster penetration of the cuticle and reduces evaporation. These formulations are rain-fast much more quickly than water-based herbicides.
- **Herbicides should be applied to rhododendron foliage in dry weather and when dry conditions are forecast for a good period after treatment (not less than 6 hours and preferably 24 hours).**
- Plant must be actively moving molecules around i.e. growing, so that the herbicide gets to the tissue where it works.
- In extreme temperatures – herbicide movement within the plant is less effective.
- If plants are in very poor growing conditions e.g. very waterlogged, then there is poorer transport within plant, poorer movement of herbicide to where it works and so treatment may be less effective or may result in a slower reaction to herbicide.

Roundup™ Biactive (≡ Roundup™ Probiactive) is the formulation of glyphosate used by Killarney National Park in all trials. It contains adjuvants and unlike some other glyphosate formulations, including some previous formulations of Roundup, is not classified even as an irritant. It is considered to be the most appropriate herbicide currently available for rhododendron control in nature conservation sites.

Herbicide Application Option 1: Stump Treatment

This method involves the application of herbicide to cut stumps immediately on cutting. It is suitable for use on plants of all diameters and can be carried out throughout the year *i.e.* it is not restricted to the growing season. Literature suggests best results in period November to April but very high kill (>99%) has been achieved in all months in trials at Killarney.

The direct treatment of stumps means that there is no standing dead regrowth to deal with. This treatment also results in a lower volume of herbicide being applied, compared with foliar treatments. The risk of damage to non-target vegetation is very significantly reduced, and operators are not required to carry large volumes of herbicide around the worksite. The reduction in the amount of follow up spraying that will be required allows the native vegetation to begin recovery immediately after the initial work phase. By using the brash generated to create a stock proof barrier (dead hedge) native vegetation recovery can proceed in the absence of any grazing pressure (see p. 39).

This method has the advantage that stump kill is achieved during the initial work phase. As with all methods, quality control is required and stumps will require checking 12-18 months after treatment.

This method of stump kill is best achieved when the stump is cut as low to the ground as possible (*i.e.* 2 - 4cm). Application of herbicide should be immediate (within minutes) and the entire above ground surface of the plant (cut stem and root collar etc.) should be thoroughly wetted with herbicide. The use of a dye (*e.g.* Methyl Violet) will help to ensure that no plants are missed. This method is best carried out by a single operator (*i.e.* the same person cuts and then treats each stump with a hand-held applicator before moving on to the next one). The manufacturer recommends the use of 20% solution of Roundup biactive for this application method, but trials in Killarney National Park have achieved >99% control with solutions down to 10% in all months of the year. Trials with 7.5% and 5% applied in November achieved effective control and summer trials with these concentrations are in progress.

Treatment must be carried out in dry weather. If clearance must proceed in wet weather, then making a high cut during initial clearance and subsequent re-cutting and application of herbicide during dry weather is also effective.

The low cut required by this method can pose difficulty where the ground is stony or where rhododendron is rooted among boulders etc. and this method is also difficult to apply to plants that are layered. Damage to saw chains from contact with the soil/stones can require frequent edging of chains. Specialized chains can cope better with this, but at the time of writing, these chains have proved difficult to source in Ireland. Trials are underway to test a variation on this method that would avoid this problem.

Table 2 Volume of herbicide used in Direct Stump Treatment (Source: P. O' Toole, KNP)

Concentration H ₂ O: Roundup	Volume Herbicide per stem Millilitres (ml)	Number of stumps treated per 5L Roundup
10:1 (10%)	0.30	1667
5:1 (20%)	0.65	765

This approach is most successful when the rhododendron is cut as close to ground level as possible.

Photograph by Peter O' Toole



The addition of a dye (left) helps to ensure that all stumps are treated. Stump death occurs within months of treatment (below).



Herbicide Application Options 2: Direct Stem (Cut Surface) Treatment

This method involves the application of herbicide directly into the stem of standing rhododendron.

It involves making a wound in the stem of a standing plant and applying herbicide (glyphosate) directly into the plant stem. The aim of the approach is to introduce the herbicide directly into the plant's transport system, which is just under the bark. Therefore it is important not to make too deep a cut into the plant stem.

This method has the advantage that when applied to a stand of rhododendron, it results in kill (and cessation of seed production), without the need to handle brush. It has been successfully used in the UK for rhododendron control in commercial sites on a significant scale. In that instance, treated plants were left to die and dry out before a track mounted machine mulched the standing dead stems in situ.

Herbicide is applied to a wound created with a hatchet, close to the base of the stem.



Photograph by Peter O' Toole

This method requires that herbicide is applied in such a way that it can get into the plant's transport system. As with other herbicide applications to rhododendron, each stem requires separate treatment, thus in multi-stemmed plants several points of application will be required. In Killarney National Park, trials of this method have been carried out using 10% and 20% Roundup, and applying to two wounds where the stem diameter is <10cm, and to three or four wounds where the diameter is greater than this. Treatments from February and April trials have achieved 100% kill. Access to the base of the plant is obviously required so that this method may be less practical in a dense or extensive stand of mature rhododendron. However, where it could be applied in such a scenario, the standing dead rhododendron might later be used for dead hedging (see p. 39).

This method may prove to be a very useful technique for the control of plants that are located in inaccessible places (e.g. on cliffs). These could be accessed by roped operatives and treated using quite small and easily held equipment (drill/hatchet and hand applicator) without the need to cut away large plants and deal with the resulting brush.

Table 3 Volume of herbicide used in Direct Stem (Cut Surface) Treatment (Source: P. O' Toole, KNP)

Concentration H ₂ O: Roundup	Volume Herbicide per stem Millilitres (ml)	Number of stumps treated per 5L Roundup
10:1 (10%)	0.26	3850
5:1 (20%)	0.50	1925

Herbicide Application Option 3: Foliar Spraying

This method is suitable for plants that are < 1.3 metres tall, and for treatment of regrowth from cut stumps.

In both instances dry conditions are required and the treated plants must remain dry for at least 6 hours after application.

All green foliage must be treated to the point just before run off.

Formulations other than Roundup™ Biactive (equivalent to Roundup™ probiactive) will be more effective if an adjuvant such as Mixture B is added.

Concentrations to use: Follow the manufacturers' guidelines. Using herbicide at concentrations higher than those recommended on the label can result in 'burning off' of the treated foliage. This then prevents uptake of the herbicide into the rootstock of the plant and the treatment will prove ineffective.

This treatment if carried out thoroughly and in good weather conditions can achieve effective kill at any time of the year, once the plant is actively growing. It should not be used in very cold weather or in frosty conditions.

In some cases, regrowth from cut stumps may be effectively treated after 3 months. In harsher climates however, control by this method may be more effective after 12-18 months growth, so that the new foliage has 'hardened off'. Ideally, there should be some mature (1 year old) and new growth present on the plant.

In any case, regrowth should be treated before it is allowed to flower i.e. 3-4 years after cutting or grow so tall that it requires re-cutting prior to foliar herbicide application.

Plants growing in waterlogged conditions may respond more slowly and, in some instances, more poorly to herbicide application, as translocation within the plant is reduced and thus movement of the herbicide into the root system is reduced. To overcome this, plants in which herbicide action is already challenged (e.g. slow growing, waterlogged plants) should be treated during the optimum conditions i.e. during the most active part of the growing season, typically June.

In all cases, the effectiveness of foliar treatment will require checking after an appropriate interval (12-18 months). Plants that have survived the first treatment or which were missed or only partially sprayed must be retreated.

It is important that non-target vegetation is not affected by herbicide during treatment. Not only will this damage the native vegetation, but in doing so it will also help to create suitable conditions for re-infestation of the area by rhododendron seed. As foliar spraying usually occurs some years after initial clearance, damage to native vegetation will knock back the recovery of the site by several years.

Water used to dilute the herbicide should be as clean as possible. Roundup™ biactive has been formulated to cope with hard water where this is an issue. When using lakes, rivers etc. as a water source, special care must be taken to ensure that caking of sprayer nozzles does not occur.

Careful and correct application of herbicide to rhododendron foliage can result in effective control.



Unless carefully executed, foliar spraying may result in damage to native vegetation, improving conditions for reinfestation by seed.

When to spray: Age of plant/regrowth

Because complete coverage of the foliage is required, plants must be low enough that operatives can easily and safely apply herbicide to all leaves. Health and safety guidelines do not allow for spraying above shoulder height using hand held applicators. Typically, foliar application is suitable only for plants that are less than 1.5 metres in height. For the sake of efficiency, and best rhododendron control, regrowth should also be treated before it has the chance to flower and set seed. This may be within 3 years of cutting, but can be a year or more later than this at sites where the growing season is shorter (e.g. Donegal). New growth should have hardened off somewhat before treatment and best control is achieved when both old (> than 1 year) and new foliage is present. For this reason, at some sites up to 2 years regrowth are allowed before foliar treating. However, treatment of regrowth after three months at Killarney has achieved good kill on some occasions.

When to spray: Time of year, Weather conditions

Dry weather is an absolute requisite when applying foliar herbicide treatment to rhododendron. The foliage must be dry and must remain dry for at least 6 hours and preferably 24 hours, when applying water based glyphosate. This requirement can present a considerable logistical challenge in rhododendron control, considering that the worst affected sites tend to be in relatively wet areas, where the number of rain days per year often exceeds 230 (cf Table A3).

At most sites, foliar treatments have been carried out during the summer months June – September. However, many operators are of the opinion that foliar treatments can be effective outside this period once the conditions are suitable for herbicide absorption into the plant (dry, not windy) and herbicide transport within the plant (greater than 5 -10°C, and not very drought stressed). Successful foliar treatments have been applied at different sites throughout the year under the requisite conditions already described.

Collateral damage

Foliar spraying of regrowth carries significant potential for damage to non-target plants. Apart from the fact that this in itself is undesirable on a nature conservation site, there is the added disadvantage that by damaging native vegetation, conditions suitable for reinfestation of rhododendron are created/improved. In theory, such damage can be avoided by very careful treatment, the use of a hood or cowl on the application lance and by applying foliar spray only in non-windy conditions. However, the need to fully treat every leaf in order to achieve successful kill, and the constraint to dry weather means that collateral damage on some scale is almost inevitable where foliar spraying is done. Where spraying is of saplings and small plants rather than regrowth from large bushes, this effect is exacerbated, and 'spot spraying' of saplings can be very deleterious to the recovery of native flora.

Non-herbicidal methods

Extraction of rhododendron rootball

Rhododendron plants can be very effectively killed by the extraction of the rootball from the soil. This may be done by extraction of the entire plant, or by extraction of the stump after cutting away of the stems and branches. This method avoids any use of herbicides and may be the only option for eradication of plants where herbicide use is not an option (e.g. on organic farms). However, the impact to tree root systems and the potential for soil compaction and disturbance caused by the use of machinery in certain habitats means that this option will only rarely be suitable in nature conservation sites.

The use of track mounted machinery can offer a relatively fast approach to rhododendron clearance by this method. A fork or bucket can extract either entire standing plants or stumps. This method is not suitable where vehicular access to a site is very difficult, where very steep slopes require clearance and where terrain (e.g. boulders) hinders the movement of machinery around the clearance site. In addition, the disturbance caused by heavy machinery to soil and to tree roots requires consideration and there is also potential for damage to standing trees, although a good operator can often avoid this. Extraction of the rootstock by this method gives good kill, although some regrowth from root fragments may require further treatment.



Stumps can be extracted with a bucket, mounted on a track machine.

Photograph by Eamonn Doran.

Rhododendron stump removal can also be carried out by hand, with the use of a pick axe or mattock. This approach can be highly effective but is extremely labour intensive and in some sites can cause moderate levels of soil disturbance.



Cut rhododendron plants and grub out stumps

This method of clearance can be used on plants ranging in size from small to large. It involves the cutting away of stems with a saw and the extraction of the rootstock using a pick or mattock. Assuming that the rootstock is carefully removed this method can deliver a very high kill rate. It also has the advantage that the vast majority of plants are killed outright during the initial work phase and the use of chemicals is minimised. As no certification is required this method is suited to volunteer programmes. As stumps are removed from the ground, they do not provide a trip hazard during later work phases on the site. Groundwork has used this method to remove >95% of large plants in some sites in Killarney. However, it is labour intensive and can be relatively slow, especially where the plants are old and very large. It is generally accepted that this method is not practical for large areas of dense infestation, especially where the work is to be done by contract or by paid staff and in easily accessible areas. On exposed sites, or where soils are very thin, soil disturbance can be an issue. Plants that are rooted beneath large rocks and boulders or whose roots are entangled with those of another tree cannot be dealt with by this method.



Pile of manually grubbed out stumps, 13 years after extraction.

Techniques for the eradication of saplings & seedlings

Although young plants and seedlings of rhododendron have relatively small impact on the habitats in which they are present, the relative speed with which they achieve maturity, producing seed and forming shade casting clumps necessitates their removal from most sites at which rhododendron is undergoing clearance. Their smaller size renders seedlings and young plants relatively easier to control than larger plants. However, their size also makes it difficult to locate all individuals and at large and very vulnerable sites systematic seedling control may be required.

There are three main methods available for seedling and small plant eradication (Table 4). Two of these rely on the use of herbicides and one is manual.

Table 4 Methods for the control of seedlings and small plants

Method	Factors critical to success	Advantages	Disadvantages/ Constraints
Snip & Treat	Must cut at ground level Weather Chemicals and concentration used	Potentially very high kill rate Lower risk of non-target damage Low volume of herbicide used No soil disturbance	Requires use of herbicides Not suitable in wet weather Discarded cut stems may obscure missed plants, especially where there is a high density of plants.
Pull	Need to remove majority of root Need to remove soil from root system Need to dispose of pulled plants carefully	Potentially very high kill rate No herbicides required Not dependant on good weather	Some soil disturbance; particularly if plants are so large as to require the use of pick or mattock. Potential for uprooting of native vegetation, especially where high densities of larger plants May be labour intensive Dry, hard ground can result in snapping off from roots.
Spot Spray	Weather Timing of application of herbicide Chemicals and concentration used Adjuvant used Complete coverage	Potentially very high kill rate Can be done as part of spraying of regrowth if that was initial clearance method	Dry weather required for spraying Very high risk of herbicide drift and damage to existing and recovering native vegetation. Can create suitable conditions for reinfestation by seed. Standing dead rhododendron shoots remain

Snip & stem treat

This method involves the cutting of small plants and seedlings and treating the stems immediately with 10% glyphosate. Stems must be snipped at ground level in order to achieve kill; otherwise multi-stemmed regrowth will occur. The use of hand-held applicators set to apply a very narrowly targeted beam of herbicide greatly reduces the risk of damage to non-target vegetation. This method is suitable for use in dry weather, appears to be effective in showery weather and trials have shown it to be effective throughout the year.

Snip & Treat method

- Plants up to c. 10cm tall are pulled; any which snap off at the base are then treated with herbicide.
- Plants up to 3cm diameter are cut at base with secateurs and treated with 10:1 solution of herbicide.
- 1 litre of 10:1 solution can treat c. 7,000 stems
- 13 microlitres (10^{-6}) is applied per stem
- This approach takes c. 10 seconds per plant.

Source: Peter O'Toole, Killarney National Park.



Snip & Treat: the plant is cut off at ground level with secateurs and 10% glyphosate is applied to the wound.

Photographs by Peter O'Toole



Pulling by hand

Plants may be pulled by hand, if necessary loosening the adjacent soil with a mattock or pick axe. If the stem snaps leaving any significant proportion of root in the soil, this may put out new growth. This is much less likely to occur in winter pulled plants than in summer pulled plants. Gently loosening the plant before pulling will reduce the chances of the stem snapping. Plants will pull more easily from damp soil than from dry soil. Plants in wet areas are often difficult to pull as the high water table forces roots to form a shallow but wide reaching mat. Plants are most easily pulled when they are between 10cm and 1 metre tall (typically 4-8 years old), but this will vary with site conditions. Be aware that plants which were previously pulled and have re-grown from roots left in the ground, will be more firmly rooted than previously untouched plants. In areas of high humidity or over wet substrates, pulled plants left lying on the ground may re-root. Knocking the soil from the roots and leaving them exposed to the air so that they will die quickly will minimise the chances of this.

Pulling by hand is quite labour intensive, and depending on the substrate and the size and density of the plants may expose mineral soil and uproot native vegetation. In some places this may increase suitable sites for reinvasion by rhododendron.

Pulling by hand does not require expenditure on herbicides, nor personnel trained and equipped to apply herbicides. It also eliminates any danger of collateral damage to non-target vegetation from herbicide drift.



Regrowth from plant that was snapped off at the base.

Ideally, all of the root should be removed when pulling seedlings and small plants. Re-growth from snapped off roots is less frequent when plants are pulled in winter months.

Pulled plants with soil and mosses left around roots will survive and may re-root completely. These plants were pulled and piled in August 2005. Photo taken February 2006.



Spot Spray

Spot spraying of seedlings and small plants is often a component of 'follow-up' work, which is the spraying of re-growth from cut stumps some years after initial clearance has been undertaken. The same conditions apply to the foliar treatment with herbicide of saplings as to regrowth from previously cut stumps (see above), and so this method can only be used in dry weather.

However, spot spraying of small plants and saplings (which are usually composed of a single stem) offers a very high risk of non-target damage from herbicide. Where there is a large density of these plants for spraying a 'blanket-spray' approach is often taken, and this is particularly damaging to non-target vegetation, in that all susceptible plants within the treatment area are exposed to herbicide damage. This not only kills off the native vegetation which has managed to recover since initial clearance was carried out (thus further delaying habitat recovery) but in doing so also promotes suitable conditions for the reinfestation of the site by rhododendron, if a seed source is present.

Spot spraying of small plants and seedlings carries a high risk of damage to non-target vegetation.

Spot spraying for seedling control carries particularly high risk of damage to native vegetation where rhododendron seedlings are small and present in high densities.



Brash Management

There are a variety of options available for the management of brash generated during rhododendron control. Where mature plants are cleared, some of the larger stems make for good firewood, and in accessible sites suitable material can be used for this. The creation of 'wood piles' on cleared sites can also be useful as 'habitat' for invertebrates and birds. Such piles can be especially beneficial in sites which formerly had very severe rhododendron infestation and so are lacking a shrub layer immediately after clearance. However, in such situations, the amount of brash produced is often greatly in excess of what is required, and even where larger stems are harvested for firewood, there remains a substantial volume of straggly, small diameter brash to be dealt with. At most sites it is necessary to manage the brash rather than leave it in situ as it is cut, because access for follow up and seedling removal is usually required.

Burning

Until recent years, the most common method of dealing with rhododendron brash was to burn it (either green or after some months/years drying) on site. This allows free access to the site for follow up work and also eliminated any risk of re-sprouting. However, new waste disposal legislation means that burning of rhododendron brash on site is now illegal. However, in special circumstances (e.g. Ramoran's Blight control) special exemptions may be obtained.

If burning rhododendron brash:

1. Set the fire in a safe place, on level ground and clear from overhanging branches that may be heat damaged, and from vegetation that may catch fire.
2. Do not burn during windy weather or when the surrounding vegetation is very susceptible to fire.
3. On substrates such as peat set the fire on corrugated iron to protect the ground from catching fire.
4. Never set fire to an established pile. Feed the rhododendron into a fire, piece by piece.
5. Never allow the fire to grow bigger than what can be controlled if necessary.
6. Pay attention to health and safety requirements
7. Never leave a fire unattended. Ensure the fire is completely out and preferably doused before leaving the worksite.

NB: Burning of rhododendron brash is illegal except where special exemption has been obtained from the relevant local authority.

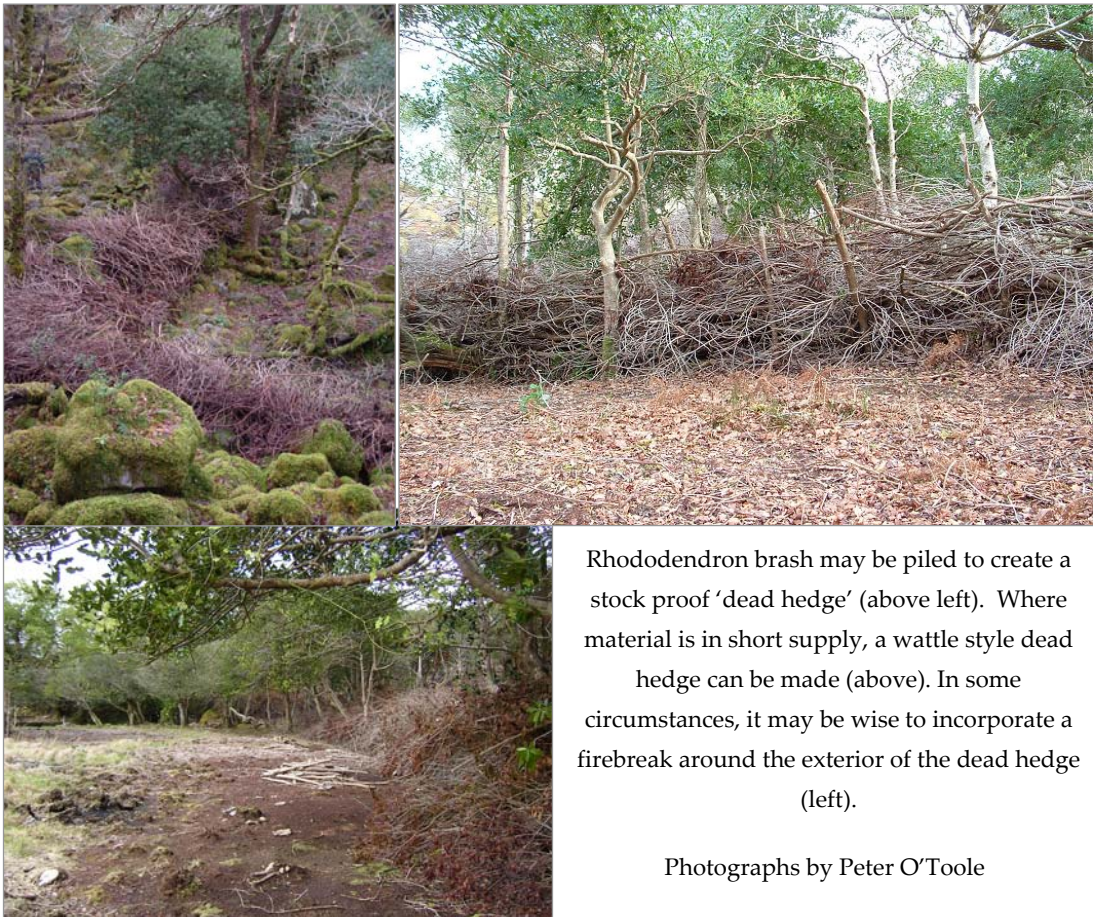
Windrow/Brash Pile

Brash may be gathered and stacked into discrete piles or windrows. This method allows easy access for follow up over most of the site area. Special attention must be paid that regrowth below or within the windrow is successfully treated and that remaining piles are safe from fire risk.

Dead Hedge

Sites that have had a severe rhododendron infestation almost always have a very restricted field layer, and where grazing animals are present, these can seriously inhibit the recovery of the native vegetation after clearance. Thus, reduction or exclusion of grazing pressure is often desirable to facilitate the recovery of the native flora. Depending on the site, this may be achieved in various ways. Complete exclusion of grazers for an initial period will assist site recovery, but at most sites it is desirable that overall grazing levels are reduced to sustainable levels, which will permit floristic regeneration, and the long term, complete exclusion of grazers is not optimal.

In Killarney National Park, rhododendron brash is carefully piled to create a mosaic of animal exclosures in the cleared area. The 'dead-hedges' are effective against deer because they provide a wide unstable barrier. On initial construction, the hedge should be c. 2 m high and 3-4 m wide. Some 'settling' of the hedge will occur and it is advisable to put aside a maintenance pile of brash for any mending of the hedge that is later required. As with any piling of material, it is important to ensure that any rhododendron stumps under the hedge are killed. Special attention should be given to these during checks of the site after initial clearance. Where deer numbers are significant and the area is large, a mosaic of individual dead hedge exclosures with clear access tracks between is preferable to one large exclosure. This will allow animals to move through the area as before and will deter them from attempting to 'break in' to the exclosure. In areas where fire is a potential hazard, it may be advisable to create a fire break around the outside of the dead hedge. Where sufficient material is not available, a 'wattle' type variation on the dead hedge may be constructed. It is advisable to include some kind of gate into each exclosure for easy access into the area for later control of regrowth and seedling control. The life expectancy of such hedges is likely to vary with climate, exposure etc. Dead hedges created at Killarney in 2001 were still very much intact in March 2006, and it is thought they are likely to act as effective barriers to grazing animals for at least 10 years. Further stock control may be required once the dead hedge has ceased to be effective.



Rhododendron brush may be piled to create a stock proof 'dead hedge' (above left). Where material is in short supply, a wattle style dead hedge can be made (above). In some circumstances, it may be wise to incorporate a firebreak around the exterior of the dead hedge (left).

Photographs by Peter O'Toole

Mulch

Mulching of brush requires that either the brush is transported to a mulching machine or that the machine can be brought on site. The former option is highly impractical in most cases, and the latter requires suitable vehicular access to the worksite. Mulching can add another cost to the clearance operation but can also result in a product, the value of which may offset the cost of the mulching. Mulching can convert brush into a more manageable format, and reduce the area required for 'storage' of brush on site.



Rhododendron brush may be mulched to create more manageable product that may be useful for paths etc.

Photograph by Eamonn Doran

Standing dead rhododendron

Direct stem treatments and foliar spraying of plants (regrowth & young plants) results in standing dead rhododendron. This can look unsightly and may pose a fire hazard, and in some sites these are reasons that necessitate the removal of such brash. More importantly, where management of re-infestation by seed is planned (especially by pulling or snipping and treating) sharp, dead stems pose a significant danger to operatives.

In Wales, stands of rhododendron that had been treated by direct stem application of herbicides were later flailed in situ using a track machine. This is not a viable option where vehicular access to and around sites is unavailable or potentially damaging.



Stem injected standing dead rhododendron was flailed in situ (left). Foliar spraying can leave large tracts of standing dead stems that can take 5-10 years to decompose (right).

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APPENDIX 1: EVALUATION OF RHODODENDRON PONTICUM CONTROL METHODS USED WITHIN NATIONAL PARKS & WILDLIFE SERVICE

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INTRODUCTION

Rhododendron is a serious problem in several National Parks and Nature Reserves, especially where these are located on or near to the sites of former demesne lands.

In order to meet the nature conservation objectives at such sites, some management of rhododendron is required so that the status of native habitats may be improved. Many different approaches to the problem have been used, with varying success. This is also true of several sites under the management of the National Parks and Wildlife Service (NPWS).

This report was commissioned by NPWS in order to bring together information from the main NPWS sites at which rhododendron control has been carried out. The objective of the work is to identify the range of control methods available, evaluate the success of each, and to identify the factors critical to the success and failure of each so that future work may be based on the lessons learned to date, and on best available information. The data gathered were used in conjunction with data from other agencies both in Ireland and abroad, to produce guidelines for the management of rhododendron in sites at which nature conservation is the main objective. The emphasis here is on effectiveness of different control methods rather than on the relative success or failure of particular clearance programmes.

SURVEY METHOD

Personal knowledge and discussion with various NPWS personnel (John Cross, Rebecca Jeffrey, Paddy O' Sullivan & Eamonn Meskell) identified 9 sites where rhododendron control had been undertaken by, on behalf of, or in consultation with NPWS at some point. Contact was made with the relevant personnel for each site and 7 of the sites were visited. Two remaining sites were not visited but data regarding rhododendron management there were gathered. For each location a site history was compiled and as much detail as possible was gathered regarding rhododendron control methods used and their success. In some cases, previous managers and contractors were also contacted.

Sites from which data were gathered

Data regarding rhododendron and its control were gathered from Glengarriff Nature Reserve, Co. Cork, Killarney National Park, Co. Kerry, Connemara National Park, Co. Galway, Union Wood, Co. Sligo, Wicklow Mountains National Park, Co. Wicklow, Glenveagh National Park, Co. Donegal, Tomnafinnog Wood, Co. Wicklow, Castlehackett, Co. Galway and Borris Wood, Co. Carlow (See Figure A1 and Table A1). All sites except Borris Wood & Castlehackett were visited between November 2005 and February 2006. Although Borris Wood was not visited for the purpose of this work, the author had previously observed rhododendron and its control at this site between July and September 2003.

Table A1 Locations of NPWS sites from which data were gathered

Site	Grid ref.	Status	Main Contact
1. Glenveagh National Park	C 04 23	National Park since 1984. SAC	Robbie Miller
2. Union Wood	G 68 28	SAC; State owned.	Tim Roderick
3. Connemara National Park	L 72 57	National Park since 1980, SAC	Ger O'Donnell
4. Killarney National Park	V 98 77	National Park since 1932. SAC	J. O'Connor, P. O'Toole
5. Glengarriff Nature Reserve	V 92 57	Nature Reserve. State owned since 1950s	Clare Heardman
6. Tomnafinnog	T 02 69	SAC; State owned since 1998.	Eamon Doran
7. Wicklow Mts National Park	T 11 96	National Park since 1991. SAC	Paul Duffy
8. Borris Wood	S 72 50	SAC. Privately owned.	Jimi Conroy
9. Castlehackett Wood	M 37 47	Owned by NPWS since 1990.	John Higgins

The Data

In all of the sites investigated, rhododendron was present prior to acquisition or involvement of NPWS. In addition, some rhododendron management had been undertaken at most sites by former non-NPWS owners and managers; in some cases such management dated back to the 1950s. Many of the current staff from whom data were gathered had become involved at their site after or during an existing rhododendron control programme. In most cases, details of previous rhododendron control were not recorded in such a way that was readily accessible to this investigation. In almost all cases, contemporary written details and evaluation of particular rhododendron control programmes were not available. Most of the information used here has been obtained by adding together various notes,

contract details and recalled information from current staff. In some cases (*e.g.* Glengarriff Nature Reserve), collation of older records is underway and will be available for future management planning. In Killarney National Park, rhododendron control methods trialled by Peter O’Toole (Park Ranger) have been detailed as work progressed, and a description is currently under preparation (O’Toole, in prep.). In addition, detailed annual reports describe the level and extent of rhododendron and clearance carried out by Groundwork in some Killarney oakwoods from 1981 to date. In Glenveagh National Park, an appraisal of rhododendron control up to 2004 has been undertaken by Robbie Miller (Park Ranger) and a draft version of this document was available for reference.

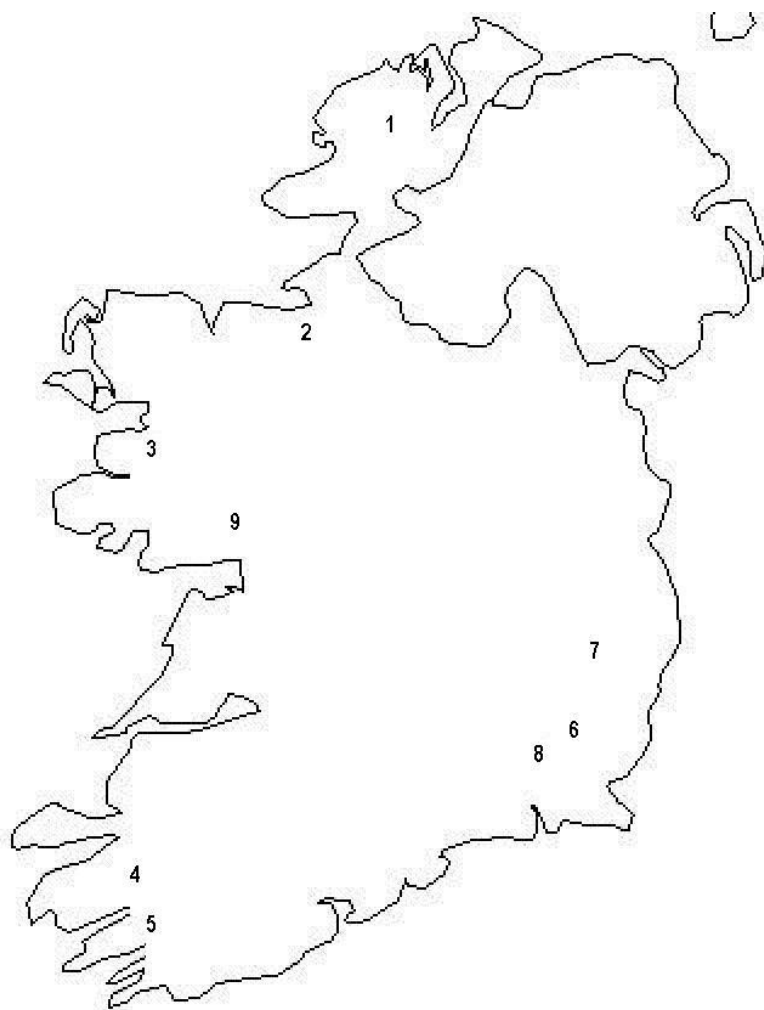


Figure A1 General location of NPWS sites from which data were gathered.

Site details as in Table A1

Habitats affected

Oak woodland was the most commonly affected habitat type in the sites investigated. However significant areas of wet heath and blanket bog were also affected and in some sites infestation in conifer plantations and conifer clear fells was also of relevance. Significant stands of wet woodland in Killarney National Park are affected by rhododendron infestation and small pockets of wet woodland in mosaic with other vegetation types at Tomnafinnogue also contain rhododendron.

The condition of the habitats affected varied greatly with age and density of rhododendron infestation. In all habitat types, increasing density of rhododendron associated with older, thicketing plants, resulted in poorer habitat condition.

Table A2 Habitats affected by rhododendron in NPWS sites.

Site	Site Area	Main habitats affected	Rhododendron Extent*
1. Glenveagh	16,958 ha	Oak woodland, heath & bog	Extensive in Glen– c.150ha distributed throughout larger area.
2. Union Wood	62 ha	Oak woodland, mixed woodland	Significant stands in c. 9ha.
3. Connemara	2,957 ha	Heath & bog	c. 25 ha of significant stands and scattered plants in additional area.
4. Killarney	10,000 ha	Oak woodland, wet woodland, heath, bog, conifer woods	Extensive stands in > 500 ha and scattered stands in greater area
5. Glengarriff	312 ha	Oak woodland, conifer clear fell	Significant stands formerly extended over most of site c. 300ha
6. Tomnafinnogue	65 ha	Oak woodland, small patches of wet woodland	Significant stands over c. 10ha and scattered plants also.
7. Wicklow	18,000 ha	Woodland edge, grassland, conifer clear fell	Formerly several clumps totalling < 10ha in total. Currently < 1ha.
8. Borris	110 ha	Oak woodland	In thickets with laurel over c.10-20ha
9. Castlehackett	65 ha	Oak/Beech woodland	Small amount (< 1 ha) among greater laurel infestation

* The area given is an estimate of the maximum area affected, including areas that have undergone clearance.

Rhododendron Ecology

Most published data regarding the ecology and reproductive traits of rhododendron in the Ireland and Britain are based on work carried out by John Cross in the early 1970s. This work was primarily based in the south west of Ireland (Killarney and Glengarriff). Many of the ecological characteristics identified by Cross, in particular with reference to reproductive biology and seedling establishment, are of vital importance to understanding rhododendron invasion at a site and when planning its control. However, as Cross pointed out, these characteristics are likely to vary with latitude and altitude.

The present study did not include measurements of growth rates or any other ecological characteristics of rhododendron at different sites. However, the study did present an opportunity to

gather observational data from site managers around the country. Such data gave some indication of differences in the behaviour of rhododendron at different sites.

Observation of regrowth (from cut stumps) clearly demonstrated a much slower rate of growth in an eastern site (Tomnafinnogue) compared with Killarney. Although no hard data were available, there was a suggestion that regrowth in areas with a relatively shorter growing season (i.e. northern sites such as Glenveagh) did not flower as quickly as in milder areas (e.g. Killarney). No site manager was in a position to give an opinion of the age at which rhododendron began flowering and Cross's (1975) assertion that flowering typically began at age 10-12 years was generally accepted. However, plants in some Scottish sites are reported to begin flowering only at c.20 years old (Colin Edwards *pers comm*), and it may be expected that first flowering might be delayed in sites at which shorter growing seasons are experienced.

It was notable that rhododendron in Tomnafinnogue purportedly flowered infrequently, even in the light shade along the banks of the River Derry. The manager at this site reported that abundant flowering happened only once every few years. A similar situation was also reported for Castlehackett. Elsewhere, it is thought that plants flower every year, although again, this is based upon recalled observation rather than any active monitoring.

At Connemara National Park it was reported that some cut stems had rooted and continued growing when pushed down into wet peaty substrates. This is apparently a rather rare occurrence at this site, and was not reported from elsewhere.

A wide range of environmental variables are found across the sites investigated. In all sites, soils are acidic but vary from podzols & peaty podzols over old red sandstone (as at Killarney) to peats and podzols over gneiss and granite (at Connemara and Union Wood) to brown podzolics and brown earths over Ordovician substrates (Wicklow).

The climate also varies across sites. Table A3 illustrates a clear trend of increasing continental conditions (generally drier conditions, with greater extremes of temperature) as one progresses from west to east. In addition, the lower average temperatures at more northerly locations result in a comparatively short growing season compared with the very mild, wet conditions to be found especially in the south-west. It seems likely that this pattern of climate is the major underlying factor that affects the variation in vigour of rhododendron growth and its invasive ability between sites in Ireland. However, soil conditions are also likely to have some effect and the existence of different varieties at different sites cannot be yet ruled out.

Table A3 Site Environmental Variables

Site	Altitude (m)*	Synoptic Weather Station	Rain Days	Frost Days	Temps °C	Annual Rainfall (mm)	Soil Type	Soil pH
1. Glenveagh	40-200	Malin Head	237	42.9	5.2 (9.3) 14.0	1060		
2. Union Wood	80-110	Claremorris	230	97	4.3 (8.9) 14.3	1143		
3. Connemara	40-100	Belmullet	249	50.3	5.6 (9.6) 14.1	1142	Peats	
4. Killarney	20-450	Valentia	239	38.7	6.6 (10.4) 14.8	1430	Podzols, Peats, Gleys	4 – 6
5. Glengarriff	10-100	Valentia	239	38.7	6.6 (10.4) 14.8	1430	Podzols	
6. Tomnafinnogue	80-150	Kilkenny	192	111.5	4.6 (9.3) 15.2	822	Brown Podzolic	4.4
7. Wicklow	140-200	Casement	185	94.3	4.6 (9.3) 15.2	711		
8. Borris	20-50	Kilkenny	192	111.5	4.6 (9.3) 15.2	822	Brown Earths	4.3
9. Castlehackett	40-167	Claremorris	230	97	4.3 (8.9) 14.3	1143		

*Altitude refers to the location of the main stands of rhododendron or range of values where rhododendron is present over wide area. Climate data is taken from the nearest synoptic meteorological station and the figure given is the 30-year average. For temperature the numbers are average daily temperature in the coldest month, (yearly average daily temperature) and average daily temperature in the warmest month. A rain day is one with $\geq 0.2\text{mm}$ rainfall.



Above – Regrowth from cut stump after 27 months, Tomnafinnogue, Co. Wicklow.



Right – regrowth from cut stump after 8 months, Killarney, Co. Kerry.

RHODODENDRON CONTROL IN NPWS SITES

Overview

A variety of rhododendron control methods have been used in the sites visited. As one would expect, sites with a larger rhododendron affected area and, especially with a longer history of NPWS management, had a wider experience in different methods than other sites.

Tomnafinnogue, Union, Borris and Castlehackett had only relatively recent histories of rhododendron management under NPWS control/influence. In the first three cases, control had been initiated since 2003, as part of habitat restoration under the Native Woodland Grant Scheme (Forest Service).

Rhododendron infestation at Connemara National Park is relatively confined and while very small areas had been cut back during the 1990s, the main programme of control was begun in 2003.

Rhododendron infestation in Wicklow Mountains National Park is so small that it is not actually considered as a problem for the park. The main blocks were controlled in the 1990s and more recently, newly acquired lands have contained (small amounts of) rhododendron that are currently under a control programme.

Glenveagh & Killarney National Parks and Glengarriff Nature Reserve are the three sites managed by NPWS that have contained the greatest extent of rhododendron and which also have the longest history of rhododendron control. In addition, a great variety of control methods have been used at these sites.

Labour Sources

Those sites where control has been carried out under the Native Woodland Grant Scheme (Tomnafinnogue, Union and Borris Wood) have relied solely on contracts. All work done at Castlehackett has also been carried out by contract.

At Connemara National Park, repeated cutting back of rhododendron stems during the 1990s was carried out by park staff. More recently, clearance has been done by contract with close supervision from park staff and it is envisaged that quality control spraying & other follow up work will be done by park staff.

At Wicklow Mountains National Park, control was carried out by park employees with some input from volunteers.

At Glengarriff, control has been carried out by contract and by permanent staff members.

In Glenveagh, cutting and spraying has been carried out by contracts, and between 1983 and 2002, Groundwork camps provided volunteers that assisted the contract clearance.

In Killarney, the wide range of control efforts has been carried out by an equally wide range of agencies. Various clearance programmes have been carried out by contractors, other areas have been managed by park staff (GOs) and others by park rangers with volunteers. Firewood schemes during the early – mid 1990s allowed local people to cut rhododendron for firewood. In addition, social employment schemes and others have done small amounts of clearance over short time spans. Various voluntary groups (local guides and scouts, visiting university and school groups), and local

conservation groups (e.g. Killarney Nature Conservation Group) have assisted with some clearance. Groundwork has run 8-12 weeks of summer workcamps clearing rhododendron since 1981.

In addition at many sites some rhododendron management was carried out by previous owners/managers (e.g. by the Forest Service at Tomies Wood and Derrycunihy, Killarney; by Coillte at Union Wood).

CONTROL METHODS USED IN NPWS SITES

Aspects of rhododendron control

In any rhododendron control programme, there are several basic aspects to be considered. These are:

1. Deal with standing plants – large and small, and manage the resulting brash
2. Kill the rootstock
3. Deal with re-infestation by seed
4. Quality control - Whatever the method, the effectiveness of control is likely to be less than 100%. Therefore, repeat visits to 'mop-up' plants that were overlooked, and to deal with any plants that survived previous control attempts will be an important part at all stages of every control programme.

The various approaches to rhododendron control that have been used in NPWS sites are summarised in Table A5 (large plants) and each is discussed in detail below. Brash management is dealt with separately (Table A9).

Control of Large Plants

Cut rhododendron and spray regrowth & spray standing plants

This has been the most frequent and widely used approach to rhododendron management. It has been used to some extent at all sites investigated here (except Borris). It involves cutting large standing rhododendron down to stump level and returning to treat the regrowth with herbicide applied using a knapsack sprayer, and treating bushes that are sufficiently small to foliar treat directly. If cutting is required, stumps are usually cut as low as practical (c. 10 – 20 cm from ground level) to minimise tripping.

Herbicide Systems used

Glyphosate is the herbicide used almost exclusively in the sites from which data were gathered. The most common approach is the foliar application of herbicide in the form of a water soluble formulation (Roundup) from knapsack sprayers. The addition of an adjuvant (usually Mixture B) is sometimes used to increase the absorption of the herbicide into the plant. More recent formulations of glyphosate (Roundup Biactive and Roundup Pro Biactive) contain extra adjuvants and can reduce the need for the use of separate adjuvants. At some sites (e.g. Glenveagh and Killarney) control with an oil based formulation of glyphosate (Nomix system) had been attempted at some point. This system has the advantage of using less volume of formula (hence the operator is required to carry lower volumes) and of being absorbed into the plant more quickly (reputedly rain-fast in 30 minutes) than water based systems. However, this system was deemed to be largely ineffective at both sites during these contracts, probably owing to problems with equipment maintenance rather than any inherent failure in the herbicide, and was not continued. It is notable however that recently the Nomix system has been further developed and that the new equipment is reputedly more robust and user friendly than before.

New methods of herbicidal rhododendron control under trial at Killarney National Park

Since 2001, trials have been ongoing in Killarney National Park (Contact Peter O’Toole, 064 35211/087 6781614) to test alternative methods of rhododendron control. An important objective of these trials has been the identification of methods of successful rhododendron control which minimise the volume of herbicide being used, and also which minimises the potential damage to native vegetation from herbicide use. Details of some of these methods are already included in this document and are also described in O’Toole (in prep.). More recently trialled methods, for which only preliminary results are available, are described below. Contact should be made with P. O’Toole before any of these methods are applied.

1. Direct Stump Treatment to higher stump

This method is a variation on the tried and tested method of applying glyphosate to the stumps of rhododendron immediately after cutting. With the original method a very low cut was required, cutting as close to the ground level as possible (2-4cm). While such a low cut is achievable, on certain soils it can present difficulties to chainsaw operatives, necessitating more frequent edging or replacement of chains. This new method which is under trial is exactly the same as the original method except that stumps are cut to 6-8cm above ground, thus preventing contact between the chain and the soil. To date, glyphosate solutions of 10% and 20% have been used and initial results are promising. Winter application (November/December) appears to have higher success than at other times of the year. The amount of herbicide used is very low (see Table 4) and there is only very low risk of herbicide damage to native vegetation.

2. Basal Bark Treatment after 3-4 weeks

This method involves cutting rhododendron to a low stump (<8cm from ground level) and returning to treat the entire basal collar directly with herbicide after 3-4 weeks. It has the advantage that the initial cutting can be carried out irrespective of dry weather, but herbicide application should be done in dry conditions. So far, trials have been carried out using 10% and 20% Roundup and initial results from late May trials are promising. Trials done in earlier Spring (before bud emergence) look less promising. The volume of herbicide used is very small (see Table A4) and application with a hand held applicator virtually eliminates the risk of damage to non-target vegetation.

Table A4 Volume of herbicide used in Direct Stump (Higher Cut) & Basal Bark Treatments (Source: P. O’Toole)

Method	Concentration H ₂ O: Roundup	Volume Herbicide per stem Millilitres (ml)	Number of stumps treated per 5L Roundup
Direct Stump (high cut)	10:1	0.45	1111
Direct Stump (high cut)	5:1	0.68	735
Basal Bark	10:1	0.45	1111
Basal Bark	5:1	0.85	588

3. Basal Bark Treatment after 12-18 months

In this method, plants are cut to as low a stump as possible, and the regrowth allowed to come on for 12-18 months. Then, the regrowth is snapped off at the base and the entire basal collar treated with herbicide as above. This method may prove useful where stumps were missed during direct stump treatment. Initial results suggest high success rates.

4. Direct Stem (cut surface) to cut stump

In this approach, the plant is cut back to a high (c. 10cm tall) stump and the stem then wounded with a hatchet (as in direct stem (cut surface) treatment) and herbicide applied. Trials have been carried out in April using 20% and 10% Roundup solution but initial results are not promising.

5. Cut, break & treat

This method involves cutting back rhododendron stems to 30-45cm (12-18") above the ground. Then, the cut stems are levered away from the rootstock with the help of a light (c.4kg/8lb) sledge-hammer. The exposed root tissues are then immediately treated with 10% Roundup. Trials during summer months suggest that this will be a very effective method of control and winter trials are underway. It is envisaged that this method will be particularly useful where there are isolated medium-large plants on rocky ground that are not easily treated by direct stump methods.



The cut, break & treat approach may prove particularly useful for isolated plants on ground that is rocky, making low cutting of the stump with chainsaws problematic. Photographs by Peter O' Toole.

6. Cut, brush & treat

This is another recently trialed method which has potential for use where rocky terrain makes low cut stump treatments difficult. It involves cutting the plant to stump level (above ground level) and returning in dry weather, after 2-3 months at which time the stump collar is thoroughly brushed with a wire brush and the entire surface then immediately treated with 10% Roundup. Summer trials of this method have given very promising results.

Table A5 Summary of Rhododendron Control Methods used in NPWS sites – large plants

	Method	Factors critical to success	Other Issues	Labour	Egs	Success
1	Cut plants to ground level & spray regrowth/ Spray standing plants <i>Nomix - poor results - because of equipment maintenance</i> <i>Round Up - most favoured generally</i>	Completeness of spraying Dry weather & 6 hours after Timing of spraying (month) Chemical and concentration used Adjuvant used Age of regrowth Quality control is required	Need for second major work phase Time delay in completing initial kill may allow flowering of regrowth High risk of herbicide drift Less effective on waterlogged plants Drift spray may result in poor site recovery & facilitate reinfestation Standing dead rhododendron complicates follow up management	pesticide cert chainsaw cert	KNP GNR GNP (Union) (T'finnogue)	≤ 100%
2	Machine mounted bucket/fork Extracts rootball/ entire plants	Entire rootball must be extracted Quality control required	Requires site to be accessible Potential damage to mature trees High soil disturbance; risk of erosion/ run off	Single machine operator	GNR T'finnoge Borris	
3	Cut plants to ground level and treat stumps	Application to stumps immediately Requires low cut Chemical and concentration used Ensure all stumps treated (dye) Dry - drizzle acceptable Quality control is required	Main kill achieved in single work phase Less herbicide used Minimal risk of herbicide drift Low soil disturbance	pesticide cert chainsaw cert	KNP GNR WMNP (Union)	≤ 100%
4	Cut plants and grub out stumps	Entire rootball must be extracted Quality control is required	Very labour intensive Moderate – high soil disturbance Stumps may produce regrowth		KNP (GW)	≤ 100%
5	Cut plants to ground level, snap off regrowth and treat eyes	Need low initial cut Application to fresh eyes Chemical and concentration used Ensure all eyes treated Dry - drizzle acceptable Quality control is required	Second work phase required Very low risk of herbicide drift No soil disturbance	pesticide cert chainsaw cert	KNP - trial	95%
6	Apply herbicide directly to plant stem	Chemical and concentration Timing of spraying	Requires access to stem base Not suitable for very 'stemmy' plants	Pesticide cert	GNR KNP - trial	? Good initial results

Reasons for poor success of foliar spraying

At some sites, there existed areas that had been cut with the intention of later foliar treatment which (usually for financial reasons) was not carried out within the 3-4 year recommended timeframe. The separation of the two work phases (initial cut and herbicide application) necessary in this control approach can result in logistical difficulties that increase the risk of the second phase either not being carried out, or not being carried out at the ideal time. There have been two approaches to this within the sites studied:

- Cutting & Spraying in a single contract – This involves the inclusion of cutting an area and returning to foliar treat regrowth after a specified time lapse, in the same contract. Usually the contractor collects the majority of his payment on completion of the cutting, with a sum e.g. 10%, retained until the spraying has been carried out. In some cases, economics, logistics and other reasons have resulted in contractors failing to return for the spraying work phase and forgoing their retained sum. The site manager then has to go through the administrative process involved in organising an alternative way to treat the regrowth and is ‘up against the clock’ in terms of the regrowth achieving flowering and/or becoming too tall to foliar spray.
- Cutting & Spraying in separate contracts – This approach carries the danger that the spraying contract may not be realised owing to budgetary constraints, change of personnel, deprioritisation of rhododendron control etc. The danger of this is high especially where sites are large and complicated with stretched resources and budgets.

In some areas, spraying appeared to have been only partially successful with < 50% kill. Many sites had been foliar sprayed repeatedly in order to achieve effective control. The most likely reasons for less than 100% kill by foliar treatment were:

- Incomplete application of herbicides – parts of plants missed, entire plants missed
- Treatment during wet weather, or rainfall soon after treatment

Where foliar treatment was not carried out as planned and regrowth allowed to achieve heights of greater than 1.5 m, it then became necessary for the rhododendron to be cut again before herbicide treatments could be applied. This second cut can be more expensive than the first cut as the plants are bushier with more stems per plant. In addition, where stands of regrowth have been left without treatment for long enough, they can flower and produce seed profusely, perhaps even more so than before they were cut.

Where rhododendron infestation is/has been extensive and occurs on difficult terrain in remote areas (as is often the case) the working conditions for control operators are quite demanding. Coupled with this, the use of water based formulations of glyphosate (which have so far proven most effective) requires operators to carry 15L knapsacks. In addition, where large volumes of herbicide are required in remote areas, access to water for refilling can pose logistical problems. At some sites, it has been reported that operators ‘walked-off’ because the conditions were so demanding, and so the occurrence of poorer quality treatment (partial/careless spraying) can be expected in such cases.

Conclusion

Foliar application of herbicide to re-growth from cut rhododendron stumps can be very successful in killing the plant. 100% kill is achievable by this method. A good understanding of the way in which

the herbicide works, and particularly the factors that affect its absorption into rhododendron, is vital so that herbicides are applied at an appropriate time. Logistic difficulties (especially the availability of sufficient dry weather) and the separation of the initial clearance work from the herbicide application increase the risk of foliar spraying being carried out at less than optimum timing. The requirement to treat every stem of every plant, the need for a 6-24 hour rain free period after treatment, and the difficult working conditions, results in less than 100% kill in most sites.



In most sites, regrowth occurs on most cut stumps (above left). Foliar application of herbicide can achieve high kill rates (above right) but standing dead rhododendron brash can remain for some years (right).



Machine Extraction

This method of clearance involves the use of a machine mounted bucket, winch or fork which can extract standing rhododendron, including the rootstock. In parts of Tomnafinnogue, this approach has been used to extract stumps after chainsaw cutting of the branches. Care is required to ensure that the main root fragments have been removed. The use of machine power renders this technique relatively fast and the vast majority of plants are killed during the initial work phase. The removal of stumps leaves the work area very accessible for follow up work. This method has been carried out by contractors at Borris, Tomnafinnogue, Castlehackett and Glengarriff. The use of this method is restricted to areas which can be easily and safely accessed by the machinery. Very steep slopes and rocky areas are not suitable. Neither is this approach suitable for remote areas which lack vehicular access. In addition, great care must be taken to ensure that standing trees and tree roots are not damaged by the machinery during clearance work. In native woodland, the impact of such large machinery is likely to be such that it would be necessary to confine the machine to existing tracks which are sufficiently stable and wide to bear the load, and where damage to the ground flora is unlikely. In most sites, such tracks, which provide adequate access to rhododendron stands, are not available and so this method is unfeasible. It is also questionable whether such machinery could be used on bog and heath sites. The extraction process results in significant soil disturbance at a level that may not be acceptable at some sites. Consideration must also be given to the risk of deposition of disturbed soil in nearby watercourses.



On some sites, stump kill is achieved by mechanical extraction of the root system. Brash may be reduced to a mulch for easier management.

Photographs by Eamon Doran

Cut plants and treat stumps

Direct application of herbicides to cut rhododendron stumps was used at many sites investigated.

In Killarney National Park, a series of trials has been carried out since 2001, with detailed recording of method and results, testing among other approaches, direct stump applications of glyphosate. These trials are being written up at present (O’Toole in prep.) and preliminary analyses are presented below. In all treatments, stumps are cut as low to the ground as possible, usually within 5 cm of the soil. Herbicide is applied to the stump immediately (within minutes) of cutting, and the entire plant surface (cut stump + any root/stem visible above ground) is treated.

Table A6 Result of various Glyphosate treatment trials (Source: P. O’ Toole, KNP)

Treatment	Months Applied	Result	Comment
20% Glyphosate	Jan, Feb, May, Jun, Jul, Aug, Oct, Nov, Dec.	100%	March & April not tested
10% Glyphosate	All months	100%	
7.5% Glyphosate	Sept, Oct, Nov	99%	
5% Glyphosate	Sept, Oct, Nov	100%	

Table A7 Volume of herbicide used in Direct Stump Treatment (Source: P. O’ Toole, KNP)

Concentration (H ₂ O: Roundup)	Volume Herbicide per stem (ml)	No. stumps treated per 5L Roundup
10:1 (10%)	0.30	1667
5:1 (20%)	0.65	765

This approach has recently been used on a large scale, by contractors in Killarney National Park, and initial results look promising for a very high kill rate. The use of dye (e.g. bright blue *Methyl Violet*) is very important to help to identify any stumps that missed treatment.

This approach has the advantage that both the cutting of plants and the initial treatment to kill the rootstock are carried out in the same work phase. Although each area will have to be checked 12-18 months after treatment (as will all areas, regardless of the control method used), the high rate of kill achievable on the first treatment means that the follow up visits should not require a large amount of herbicide application to deal with regrowth. However, it has been reported from some sites (not investigated here) that the small amount of regrowth from treated stumps is very stunted and not suitable for foliar spraying until several (2 or more) years after initial treatment. This can cause logistical difficulties when contract details are being arranged or when the rhododendron management is being carried out within the 5-year constraint of a Native Woodland Scheme grant. However, alternative methods (such as knocking off of regrowth and treating the growth buds) could be used to overcome this logistical difficulty.

The direct treatment of stumps means that there is no standing dead regrowth to deal with (see brash management). This treatment also results in a lower volume of herbicide being applied, compared with foliar treatments. The risk of damage to non-target vegetation is very significantly reduced, and operators are not required to carry large volumes of herbicide around the worksite. The reduction in

the amount of follow up spraying that will be required allows the native vegetation to begin recovery immediately after the initial work phase.

The low cut required by this method can pose difficulty where the ground is stony or where rhododendron is rooted among boulders etc. and this method is also difficult to apply to plants that are layered. Damage to saw chains from contact with the soil/stones can require frequent edging of chains. Specialised chains can cope better with this. Trials are currently underway in Killarney to investigate the success of this method on plants cut to 6-8 cm above ground.



The addition of a dye (left) helps to ensure that all stumps are treated. Stump death occurs within months of treatment (below).



At Glengarriff Nature Reserve, several variations on this method had been used during the 1970s and 1980s. Table A8 below gives broad detail and outcome from these methods. The results given here were derived from general observation, queried several years after the fact.

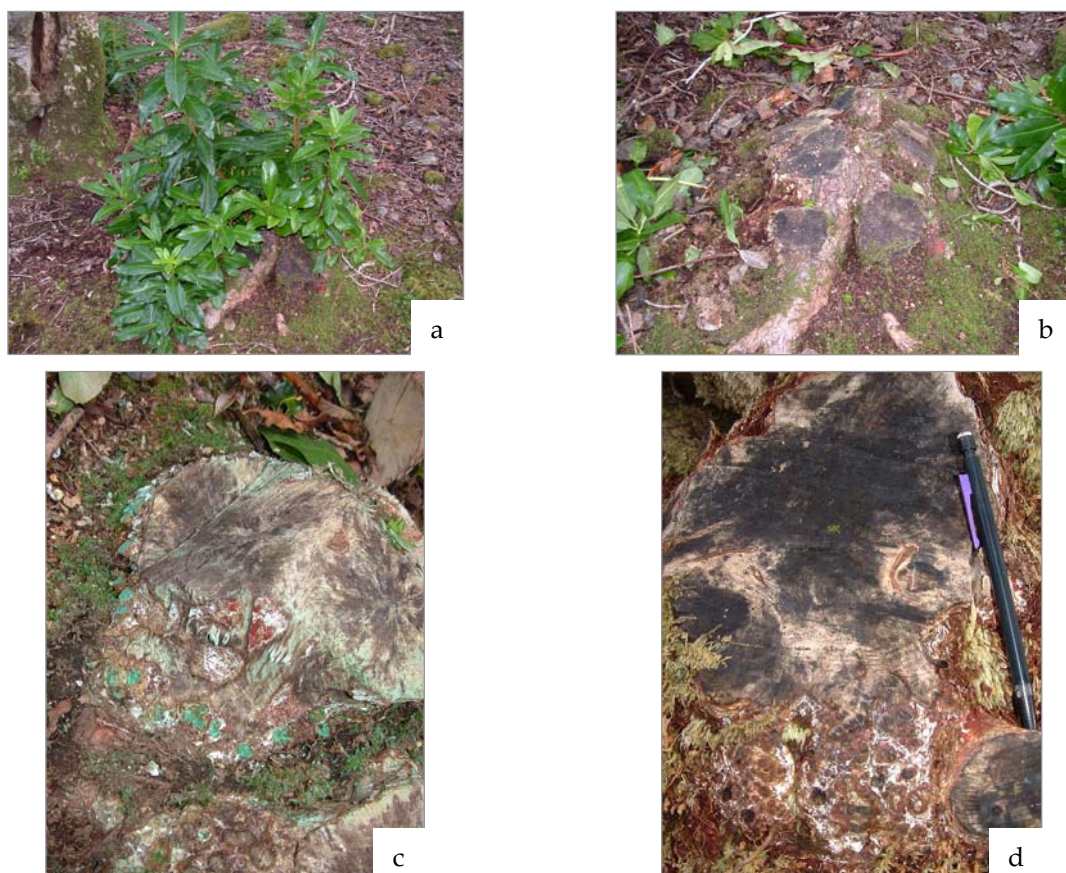
Table A8 Results of field trials held in Glengarriff Nature Reserve

Treatment	Result	Comment
Diesel + Burnt Engine Oil	Stunted regrowth – No kill	
Urea + Roundup	Good kill – c. 90%	
20% Roundup	70% effective in winter.	Less effective summer.

Similarly, some direct stump treatments were used in Wicklow Mountains National Park during the 1990s. It appears that 10% glyphosate was used but detailed information was unavailable and the percentage kill achieved is not known, as some follow-up spraying was done to ensure successful control. As part of more recent control programmes, stump treatments were also being used at Union Wood and Glenveagh National Park, but results are as yet unavailable.

Cut plants low and treat regrowth eyes

This method is another under trial at KNP. It involves the same low cut as described under 4 (above). In this scenario however, the cut stumps are allowed to shoot for 12-18 months (Pic 7a below). Then regrowth is knocked off by hand (Pic 7b) and the abscission point ('eyes' from which the regrowth arose) are spot treated with 10% glyphosate (Pic 7c). This method has been tried with herbicide application during February, August and November and has given very high (>99%) kill rates (Pic 7d). This method reduces the volume of herbicide that is used (and carried by operatives) and also has lower potential for damage to surrounding native vegetation. This is a good follow up method for use when some stumps were missed during initial clearance (where direct stump treatment was the method) and where there is any regrowth from treated stumps.



Regrowth from cut stumps (a) is knocked off after 12-18 months (b) and the resulting 'eyes' treated with glyphosate (c), resulting in stump death after several months (d).

Application of herbicide into standing plant stem

This method (sometimes referred to as 'stem injection') involves the application of herbicide directly into the stem of standing rhododendron. It has not been used widely within NPWS to date, but has been used on an occasional basis in Glengarriff Nature Reserve. In that instance the method involved the cutting away of the bark around each stem with a penknife, and spraying the wound with glyphosate at foliar spray concentrations. This was found to be a fairly effective summer treatment. However, it was not deemed applicable for large stands of rhododendron, but rather for individual plants that may have been missed during initial clearance.

This method has been under trial in Killarney National Park since Spring 2006. Mature plants (from about 1m tall) were wounded with a hatchet close to the base of the stem and glyphosate immediately applied to the wound. Solutions of 10% and 20% have been trialled in February, April and May and initial results are very promising.

This method has the advantage that when applied to a stand of rhododendron, it results in kill (and cessation of seed production), without the need to handle brush. It has been successfully used in the UK for rhododendron control in commercial sites on a significant scale. In that instance, treated plants were left to die and dry out before a track mounted machine mulched the standing dead stems in-situ.

Herbicide is applied to a wound created with a hatchet, close to the base of the stem (left)

Once the plants have died, a track mounted flail mulched the standing dead material in situ (right).



This method requires that herbicide is applied in such a way that it can get into the plant's transport system. As with other herbicide applications to rhododendron, each stem requires separate treatment, thus in multi-stemmed plants several points of application will be required. Access to the base of the plant is obviously required so that this method may be less practical in a dense or extensive stand of mature rhododendron. This method can be applied in showery weather or light rain.

Direct stem application may prove to be a very useful technique for the control of plants that are located in inaccessible places e.g. on cliffs. These could be accessed by roped operatives and treated using quite small and easily held equipment (drill/hatchet and hand applicator) without the need to cut away large plants and deal with the resulting brush.

Control of seedlings, saplings and small plants (single stems, < 1.8m)

General approach to seedlings, saplings & small plants

Generally, small plants and seedlings were found to be considered secondarily to large clumps and thickets of infestation at the sites visited. Seedling control was always an issue that was acknowledged as requiring attention but was rarely worked specifically into management programmes, especially as an issue separate to 'follow-up' spraying of regrowth from cut stumps.

Where seedling (new infestation and re-infestation) work was carried out as a specific work phase it was almost always by permanent staff and/or volunteers, and very rarely, if ever, as part of a contract.

However, more recently (mid 2006) a major contract whose emphasis is clearance of reinfestation (mostly by seedlings) has been undertaken at Killarney National Park.

At Killarney National Park, Staff have developed a seedling and sapling control method using secateurs and hand-held herbicide applicators, and this has been used successfully by staff, contractors and volunteers.

In Glengarriff, 3 permanent staff carry out seedling work in different management blocks as and when required. Because the low grazing levels at this site allow for relatively fast recovery of the native ground vegetation, seedling sweeps of cleared areas are preferred within 1 or two years of initial clearance. At this site a variety of methods including pulling, spot spraying and snipping and stem treatment are used.

In Killarney, areas worked in by Groundwork have been subjected to a seedling orientated clearance programme. Primary clearance is carried out from the 'outside-in' to minimise seed input into cleared areas. Each work area is systematically swept for seedlings 2-3 years after the initial clearance and again 8 years after initial clearance and every 6-8 years thereafter so long as an external seed source remains. Each sweep is timed so that no plant has the chance to reach maturity and produce seed within the site once initial clearance has been done and the maintenance schedule initiated. With this programme, seedling work is given priority and clearance of new areas is undertaken only when maintenance commitments for any given year have been completed. In theory, as time goes on reinfestation from seed should be reduced and the effort required to maintain cleared areas free should also decrease.

Methods for seedling and small plant control

In most of the sites studied, small plants were present in some abundance and required management. Three approaches to the treatment of small plants are considered:

1. Pull
2. Spot spray
3. Snip & stem treat

1. Pull

This simply involves the pulling of the entire plant from the soil. The ease and effectiveness with which this can be done depends on the age and size of the plant, the substrate in which it is rooted and the wetness of the soil. In order to be effective, care must be taken that the entire root is extracted, rather than simply snapping off the plant at the stem base. However, a small scale study in Killarney National Park has suggested that roots left in the ground in winter were less likely to result in re-growth than roots left in the ground in summer (P. O' Toole, *pers comm.*). For larger plants, loosening the root area with a mattock or similar tool will aid the effective removal of seedlings and small plants. Once pulled, plants must be carefully dealt with: in damp or wet conditions re-rooting and subsequent re-establishment can take place. Larger plants (bigger than fist sized) can be hung in trees where the roots will quickly dry out. Pulling of seedlings is often carried out by voluntary groups (e.g. various groups at Killarney, including Groundwork).



Roots left in the ground from pulled seedlings can give rise to new growth. Pulled seedlings and small plants must have their roots exposed to dry out and die. Piles with soil still attached can continue growing.

2. Spot Spray

Spot spraying of seedlings and small plants is often a component of 'follow-up' work, which is the spraying of re-growth from cut stumps some years after initial clearance has been undertaken. The same conditions apply to the foliar treatment with herbicide of saplings as to regrowth from previously cut stumps (see above). However, spot spraying of small plants and saplings (which are usually composed of a single stem) offers a high risk of non-target damage from herbicide. It is also dependent on suitable weather.

3. Snip & stem treat

This method involves the cutting of small plants and seedlings and treating the stems immediately with 10% glyphosate. Stems must be snipped at ground level in order to achieve kill; otherwise multi-stemmed regrowth will occur. The use of hand held applicators set to apply a very narrowly targeted beam of herbicide reduces the risk of damage to non-target vegetation. This method is suitable for use in dry weather. This approach has been used with very high success (>99%) throughout the year at Killarney, and in Glengarriff.

Approach to Seedlings used in KNP

- All plants up to 10cm in height are pulled, and if the stems break then herbicide is applied to the root.
- Larger plants (up to 3cm diameter) are cut to ground level and spot treated with 10% glyphosate.
- It has been estimated that by using this approach, c. 7,000 plants can be treated by 1 litre of glyphosate (concentrate) and that it takes c. 10 seconds to treat each plant.



Single stemmed plants may be cut with secateurs and the stem treated with glyphosate (a, b).

Brash Management

The brash generated during rhododendron control at NPWS sites has been dealt with in a variety of ways (summarised in Table A9). The type of brash generated depends on the nature of the infestation and the way in which plants have been treated. In some accessible sites, suitable material has been harvested for firewood.

Burning

Until recent years, the most common method of dealing with rhododendron brash was to burn it (either green or after some months/years drying) on site. This allows free access to the site for follow up work and also eliminated any risk of re-sprouting. However, new waste disposal legislation and an increased consciousness of the negative environmental effects of burning have resulted in a reduction in the popularity of this approach to brash and many sites are opting for alternatives.

Leave in-situ

In some plots (e.g. at Killarney & Glengarriff) brash was left in situ after cutting by the chainsaw team. In both cases however the method of stump kill was foliar treatment of re-growth and so access to the plot by sprayers was required later. The sitting brash rendered access difficult and dangerous, and in both cases it was necessary to later remove and pile the brash to provide safe access. Where direct stump treatment is in use, lying brash also prevented access. In addition, at sites where new rhododendron seedlings are likely to establish and require clearance, good site access after initial clearance is required. There is some suggestion that this delayed brash management may be more economical than stacking as the rhododendron is cut, as skilled labour is not required to carry out the stacking. However, logistically it adds another work phase to the programme. If brash handling is left until just prior to herbicide treatment there is the risk of wasting good weather opportunity which very often is a major limiting factor in successful herbicide treatment. Clearing brash which has been left to settle may be more difficult than piling it as it is cut, and delaying the piling will result in disturbance to invertebrates and other wildlife that may have been using it as a habitat while it was in situ.

If the risk of re-growth from cut stumps were eliminated (e.g. by successful direct stump treatment or uprooting stumps) and if there was no seed input into the cleared area, then leaving brash in situ may have the effect of creating a barrier to grazing animals, and provided that it did not reduce light levels excessively, it may facilitate speedier recovery of the field layer (but see 'dead hedging' below). In sites where there is a risk of fire, lying brash can pose a fire hazard and a general barrier to safe access to the woodland area. In some instances, lying brash may hinder the natural regeneration of native tree species.

Windrow

In some sites (e.g. Union Wood) rhododendron brash is windrowed on site during the initial clearance.

Dead Hedge

The concept of using rhododendron brush as a barrier to grazers has been applied at various locations (e.g. Glenveagh, Union Wood). This approach has been an inherent part of trials at Killarney National Park since 2001 (O'Toole, in prep.) and has been used in large scale contracts there since 2005.



Rhododendron brush may be piled to create a stock proof 'dead hedge' (left). Where material is in short supply, a wattle style dead hedge can be made (right).

Mulch

Some sites (Tomnafinnogue, Castlehackett) have mulched their rhododendron brush during initial clearance. In Tomnafinnogue, cut branches and extracted root balls were manually fed into a commercial 'chipper', and a relatively fine mulch was produced. Piles of this mulch were left on site and carefully monitored over the period 2003-2006 to ensure that mulched fragments would not re-sprout. No sprouting from these mulch piles has been observed. The mulch produced is suitable for surfacing on tracks and pathways and is being used for this purpose at Tomnafinnogue.

At Castlehackett, windrowed cherry laurel & rhododendron brush was mulched in situ by a machine mounted drum & flail. This resulted in a medium – coarse mulch, from which some re-growth (probably mostly cherry laurel) resulted. However, the mulched pile is easily walked upon and is easier to control with spraying than the windrow prior to mulching.



The mulch pile (above right) showed no sign of regrowth after 24 months.

Standing dead rhododendron

In most sites visited, foliar spraying of regrowth from stumps had resulted in large areas containing standing dead rhododendron. In all sites, standing dead rhododendron was left to rot away naturally. Recent contracts in Glenveagh National Park require that “All rhododendron, including sprayed dead bushes and cut bushes, must be removed/burned from within view/30m of areas of high amenity (main glen roadside/viewpoint path) and in all other areas where density of sprayed rhododendrons may prevent future access for spraying and/or seedling removal”. No method of removing standing dead rhododendron was found to have been carried out in any of the sites visited for this study.

Where direct stem treatments are being used in Killarney National Park, it is planned to cut the standing dead plants 12-24 months after initial treatment and to use the resultant brush for the creation of dead hedges.

Table A9 Summary of Rhododendron Brash Management Techniques at NPWS Sites

	Brash Treatment - Dense stands	Advantages	Disadvantages
1	Leave in situ	Less labour required during initial clearance May deter browsing animals from site Brash can act like shrub layer – bird perches, invertebrate habitat etc.	Inhibits access for stump/re-growth follow up Inhibits access for seedling follow up Rotting biomass may affect soil chemistry Lying brash poses a fire risk. May trap litter and inhibit vegetation growth
2	Leave in situ, pile after several months	Faster initial clearance Only chainsaw labour used during initial clearance Can employ unskilled labour for piling Acts as barrier to browsers and shelter to vegetation for duration in-situ	May be more difficult to clear collapsed and tangled brash Adds an extra work-phase to clearance programme Will disturb any wildlife that has used brash as habitat Fire risk
3	Burn green/after drying out	Removes material from site, so easy access for follow up management	Risk of air pollution Danger of damage to other vegetation Currently illegal: Waste Management & Air Pollution Acts.
4	Windrow/discrete piles	Leaves site relatively clear for access for follow up management May provide shelter to recovering vegetation and act as wildlife piles	May require control of re-growth/seedlings from within/under pile Piles may pose fire hazard
5	Dead Hedging	Leaves site relatively clear for follow up management Excludes browsers to facilitate native vegetation recovery Act as shelter and habitat for wildlife	Requires control of re-growth/seedlings from under hedge Hedge may pose fire hazard and require fire break
6	Mulch	Can provide usable material (paths and gardens) Mulched stumps much less likely to re-sprout	Requires access for mulcher Mulcher can be expensive Must then dispose of mulch/accept mulch piles
7	Remove from site	Leaves site clear for follow up management Firewood may provide income source to off set clearance cost	Requires good access Requires labour

CONTROL STRATEGY & MANAGEMENT PLANNING

In many sites where rhododendron was restricted to a relatively small area, the removal of the main bodies of infestation has been quite effective in reducing, if not completely eliminating, the infestation to an acceptable level. At larger sites where the removal of all large stands of seed producing rhododendron is not feasible in the short to medium term, management planning is much more difficult and important. This is particularly relevant in the cases of Killarney and Glenveagh National Parks. The habitat condition after severe rhododendron has been cleared is particularly susceptible to reinfestation from seed, and slow recovery of the native vegetation, further inhibited by grazing, exacerbates the problem. In such large and complicated sites, where rhododendron infestation is present over a wide area, in various different blocks and habitats, the questions of where to begin and how to proceed can have major impact on the success of management.

A questionnaire was circulated to staff at 8 of the sites investigated in order to ascertain how rhododendron management planning had been carried out to date.

At most of the sites responsibility for rhododendron management lay with one person who also had general responsibility for the entire site. In some cases, especially on larger sites where there were relatively many personnel, a team of people contributed to decision making with regard to rhododendron management. Most decision making was done on the basis of site visits and meetings. Documents outlining the rationale behind decisions were rarely produced.

While many sites had general maps that included information on where specific contracts or clearance programmes were carried out, only at a few sites was the nature of the rhododendron infestation mapped. While the extent and nature of rhododendron was known at all sites, a whole site map with detailed rhododendron extent and description was not available for most sites. Such maps are in preparation for some sites.

In most cases, rhododendron management was carried out for individual stands as per annual business plans, rather than as per a specific rhododendron management plan, spanning several years. However, in some sites a long term rhododendron management plan is under preparation. At several sites, rhododendron management is being carried out under the Native Woodland Grant Scheme (Forest Service) and management planning is contained within the 5-year site plan produced jointly by an ecologist and forester.

In all cases, the primary motivation for rhododendron management was habitat conservation, but some clearance had also been carried out for access. In most cases, the details of control methods and their success were not recorded in a specific format. Some details regarding control methods were discernable from copies of tenders and contracts, and while visual evaluation of clearance work was always carried out, no specific reporting structure on this was in place.

In all cases, the control methods used were chosen as they were believed to be the best available option, but some site managers said that lack of suitable labour also influenced the choice of method. Many site managers felt that more information regarding different methods of rhododendron control would be useful.

Habitat Restoration

At all sites investigated, the primary purpose of rhododendron management was restoration of native habitats, usually woodland, and more rarely, heath or blanket bog. Severe rhododendron infestation in any habitat almost always eliminates any ground, field or low shrub layer that might otherwise be present and the post clearance condition at such sites is often very poor. Here, bare soil is usually dominant, often with a thick 'sponge' of rhododendron humus that may be slow to recolonise with native flora. Where a seed source remains, this situation renders the cleared site very vulnerable to reinfestation by rhododendron, and this is exacerbated by grazing of the native vegetation (rhododendron is poisonous to and so avoided by grazing animals). Where grazing pressure is low (e.g. Glengarriff) native vegetation recovery is faster, and this in turn limits the extent to which rhododendron can re-establish. (The small seeds of rhododendron require mossy or open ground to establish.) Recovery of native flora after very severe infestation will be best achieved under very low grazing pressure and this may require a significant reduction in the numbers of grazing animals; in extreme situations the complete exclusion of grazers may be required in the short-term. At many sites, exclusion of grazers is achieved by fencing, but in the long term, complete exclusion of grazers is not a desirable option from an ecological point of view, as low grazing levels are a natural part of the woodland ecosystem and promote biodiversity. There is some evidence that holly may become over-dominant in such scenarios (e.g. Camillan Wood, Tomies Wood, KNP), and succession to oak woodland has been known to be arrested by holly at some English sites.

CONCLUSIONS

A wide variety of rhododendron control methods have been used at NPWS sites over the past 30 or more years. No single method is applicable at every site and under all conditions. In most sites, a combination of various methods is required to achieve effective rhododendron control. All of the methods described can give complete control if carried out correctly and under optimum conditions. (However, the chemical control of plants growing in waterlogged areas requires some further investigation.) It is evident that even where mechanical and manual methods are employed, some herbicide application will be necessary to achieve total control. In all cases, logistical details can have a significant impact on the success or failure of the chosen method, and in many cases poor or partial success can be attributed to logistical difficulties and/or incorrect application of a particular method.

Management planning for conservation purposes is a relatively new concept in Ireland, and makes further demands on the already stretched time resource of site managers. However, detailed management planning for rhododendron control can significantly improve the effectiveness and efficiency of management, especially where large, complex sites with extensive rhododendron infestation are involved. Much of the current knowledge about the detailed methodology and success/failure of different control techniques is heretofore unrecorded, and based on recalled observation rather than on contemporary records and active evaluation.

Most of the rhododendron management programmes which were analysed here were focused very much on the primary clearance of large, established stands of rhododendron. Few management programmes were focused on sparsely infested areas or on maintaining cleared areas free from reinfestation. The early detection and control of invasive species is the most effective and efficient way to maintain good habitat status, and this is certainly true for rhododendron. Some programmes had already taken this concept on board to good end, and many of the more recent programmes were factoring this into their plans.

The recent availability of multi-annual budgeting (from NPWS and under the Native Woodland Grant Scheme) should have a positive impact on the running of effective contracts for rhododendron clearance. However, there is some concern about the availability of suitable labour for rhododendron clearance work and this has already influenced the choice of control method used at some of the sites investigated here.

In most sites visited, a strategic approach to rhododendron management had been recently adopted and this usually involved an appraisal of the situation at the onset of the more recent management programmes. In addition, the fact that rhododendron infestation is a trans-boundary problem is also recognised, and there is a need for the development of some system whereby rhododendron outside of NPWS controlled conservation areas may also be tackled. As rhododendron control strategies within NPWS sites increase in effectiveness and achieve their objective, the problem of nearby external seed sources will become increasingly relevant.

Overall, there appears to be a growing confidence in the methods now available for rhododendron control and with a shift towards strategic management and the allotment of sufficient resources, successful long term rhododendron control appears to be an achievable goal at many sites.

RECOMMENDATIONS

The following recommendations are made:

- Issue information and management guidelines to NPWS staff.
- Establish a communication network for information sharing between sites/regions regarding rhododendron and also other invasive species.
- Host a training event about rhododendron with particular emphasis on aspects of rhododendron ecology affecting its invasiveness, control methods, including practical demonstrations of methods and management planning for effective rhododendron control.
- Establish a method of recording and evaluating methods trialled at different sites, and any relevant issues arising from clearance programmes.
- Draw up a list of contractors experienced and competent in various rhododendron control methodologies.
- Investigate a landscape scale approach to rhododendron management, working with other landowners – private individuals, local authorities, Coillte, Department of Agriculture etc. This is especially relevant where rhododendron on neighbouring lands is a significant issue e.g. Connemara, Killarney, Glengarriff, Union Wood, Tomnafinnogue.
- Produce material for members of the public to explain the need for rhododendron management thus improving public relations and gaining public support for measures.